United States
Department of
Agriculture

Department of the
Interior

Forest Service

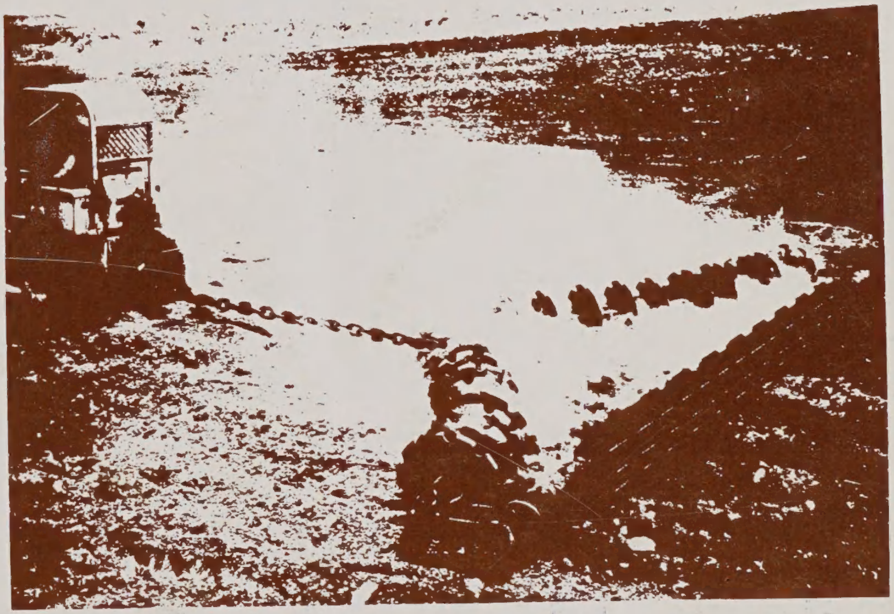
**Equipment
Development
Center**

**Missoula, MT**

**San Dimas, CA**

# Vegetative Rehabilitation & Equipment Workshop

## 38th Annual Report
## Rapid City, South Dakota
## February 14 & 15, 1984





November 1984
2200—Range
8422 2806

The Vegetative Rehabilitation and Equipment Workshop is an organization of Federal and State agencies and private groups working to improve rangelands and further range equipment technology. Government officials and industry and university representatives from other countries also participate.

To accomplish its goals, the Workshop evaluates and develops equipment and prescribes specifications and standards for equipment purchase, maintenance, and use. The Workshop also functions as a clearinghouse for the interchange of information and the dissemination of material describing its activities and accomplishments.

Those interested in participating in the Workshop should contact its chairman, Ray Hall, Range Management Staff, USDA Forest Service, P.O. Box 2417, Washington, D.C. 20013.

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*Cover: Prototype disk-chain. Disk-chaining shows excellent promise as a cost-efficient method of preparing a seedbed on debris littered rangeland with cost reductions of up to 50 to 75 percent compared to seedbed preparation by standard disking. This results in seedbed preparation costs almost equal to chaining costs but with the quality of disking. Single-tractor pulling has resulted in a 36 percent reduction in draft requirements compared to the two-tractor diagonal pulling method.*

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**PARTICIPANTS**

U.S. Department of Agriculture
U.S. Department of the Interior
State and County Organizations
State Wildlife Agencies
Industry Representatives (Chemical, Equipment, Mining, Seed)
Educational Institutions
Ranchers
Foreign Countries

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United States Department of Agriculture

Forest Service

WO

February 23, 1984

Dear VREW Participants:

First, I would like to thank everyone who participated in the 1984 workshop in Rapid City. Although our attendance was down somewhat from previous years, most people I talked to felt the meeting was very worthwhile.

A special note of gratitude to Craig Whittekiend for handling the arrangements for meeting room, equipment, and registration; to Jack Bohning for his very appropriate remarks in the opening address, and to the participants on the panels discussing noxious weed control and mined-land reclamation. From these discussions it is obvious that although it maybe slow and costly, we are making progress in range revegetation and improvement.

I believe the emerging noxious weed problem is one of the more serious issues facing western rangeland managers now and in the near future. A viable program is dependent on an adequately financed research and control effort, fully coordinated with the affected Federal and State agencies private landowners and local weed control districts. VREW can plan a significant role in that effort and I respectfully request your support

The state-of-the-art in mined-land reclamation is at a much higher level than perceived by many publics. VREW has an opportunity and a responsibility to take a more active role in the dissemination of current technology on methods and equipment.

Pat Currie from the Fort Keogh Range Research Station made a presentation on a prototype machine he calls the RIM (range improvement machine) and submitted a proposal for assistance to do some additional developmental work on a second generation model. The machine generated considerable interest among range people from the central and northern Great Plains and appears to have broad application potential. Pat's proposal has been turned over to the Arid Land Seeding Workgroup for investigation and recommendations.

In past years range equipment development work has been carried on at both the San Dimas and Missoula Equipment Development Centers. In an effort to be more cost effective, the Forest Service is shifting all range equipment development responsibility to the Missoula Center. Our contact at the Missoula Center is Dick Hallman. Dick can be reached at 406-329 3946 for FTS 8-585-3946. I urge you to call him if you have a revegetation equipment problem or question. Unfortunately, in making this move we will lose the services of Dan McKenzie of the San Dimas Center. Over the years, Dan has made significant contributions to the investigation, development, and testing of specialized range improvement materials and equipment. We sincerely thank him for his past efforts and will miss his help in the future.

The 1984 VREW Workshop was held as a concurrent session with the Society for Range Management convention sessions on a trial basis. Although this worked out well from a logistical standpoint, it is the feeling of both SRM leadership and the VREW steering committee that the concurrent sessions resulted in lowering attendance at both sessions. With this in mind, we are tentatively planning to return VREW to the traditional Sunday-Monday schedule in 1985 The 1985 workshop will be in Salt Lake City, February 10 and 11 at the Hotel Utah. If you would like to make a presentation or would like any specific information presented, please let me know.

Sincerely,

Randall R. Hall

**RANDALL R. HALL**
Chairman, Vegetative Rehabilitation and Equipment Workshop

# Contents

# Agenda

**Meeting Theme. Vegetative Rehabilitation in the Heart of America's Rangelands**

## Tuesday—Feb. 14

**Welcome** . . . . . . . . . . . . . . . . . . . . . . . . . Craig Whittekiend
SRM Meeting Committeeman

**Introductions** . . . . . . . . . . . . . . . Ray Hall, *Chairman,* VREW

**Introductory Remarks: Role of VREW in Rangeland Management** . . . . . . . . . . . . . . . Jack Bohning
Past President
Society for Range Management
Prescott, AZ

**Panel Discussion:**
**Chemical, Thermal, and Mechanical Control of Noxious Weeds—Progress and Prognosis**

Panel Moderator: . . . . . . . . . . . . . . . . Dr. Russell J. Lorenz
Agricultural Research Service, Mandan, ND

Panel Members: . . . . . . . . . . . . . . . . Dr. Ardell J. Bjugstad
Forest Service, Rapid City, SD

Dr. Harold P. Alley
University of Wyoming, Laramie, WY

Dr. Calvin G. Messersmith
North Dakota State University, Fargo, ND

**Panel Discussion:**
**Biological Control of Noxious Weeds—Progress and Prognosis**

Panel Moderator: . . . . . . . . . . . . . . . . Dr. Lloyd A. Andres
Agricultural Research Service, Albany, CA

Panel Members: . . . . . . . . . . . . . . . . . . . Dr. C.J. DeLoach
Agricultural Research Service, Temple, TX

Dr. Norman Rees
Agricultural Research Service, Bozeman, MT

**Chemical Plant Control Workgroup** . . . . . . . . . . . . Ray Dalen
Forest Service, Albuquerque, NM
Foam Marking Systems for Rangeland Sprayers . . . . . . . . . . Maurice R. Gebhardt
Agricultural Research Service, Columbia, MO

**Mechanical Plant Control Workgroup** . . . . . . . . . . Gus Juarez
Bureau of Land Management, Grand Junction, CO
Mechanical Control of Sagebrush . . . . . . . William F. Davis
Forest Service, Ogden, UT

**Thermal Plant Control Workgroup** . . . . . . . . . William F. Davis
Forest Service, Ogden, UT
Merritt Island Brush Burning . . . . . . . . . . . . Dick Hallman
Forest Service, Missoula, MT

**Progress in Nonstructural Range Improvement in the Northern Great Plains -Future Needs** . . . Dr. Robert Gartner
South Dakota State University
Rapid City, SD

**Range Improvement Machine** . . . . . P.O. Currie and R.S. White
Agricultural Research Service, Miles City, MT;
L.R. Erickson
Montana State University, Bozeman, MT

**Structural Range Improvements Workgroup** . . Billy H. Hardman
Forest Service, Missoula, MT
Low Cost Diagonal Fence Strainer . . . . . . Dan W. McKenzie
Forest Service, San Dimas, CA;
W.F. (Bill) Currier
Forest Service (ret.), Albuquerque, NM
Range Water Systems Improvements Project ED&T OE01D40. . . . . . . . . . . Dan W. McKenzie
Forest Service, San Dimas, CA
Solar-Powered Pumping . . . . . . . . . . . . . . . Mike Easterly
Grundfos Pumps Corp., St. Louis, MO

**Open Discussion from the floor**

## Wednesday—Feb. 15

**Plant Materials Workgroup** . . . . . . . . . . . . . . . .Wendell Oaks
Soil Conservation Service, Los Lunas, NM

**Seed Harvesting Workgroup**. . . . . . . . . . . . . . . Steve Monsen
Forest Service, Provo, UT

**Seeding and Planting Workgroup** . . . . . . .William J. McGinnies
Agricultural Research Service, Fort Collins, CO
Seedbed Preparation—The Forgotten Step
in Range Seeding. . . . . . . . . . . . . . .William J. McGinnies
Agricultural Research Service, Fort Collins, CO

**Arid Land Seeding Workgroup** . . . . . . . . Harold T. Wiedemann
Texas Agricultural Experiment Station, Vernon, TX
Triangular Disk-Chain Activities . . . . . Harold T. Wiedemann
Texas Agricultural Experiment Station, Vernon, TX
Woodward Laboratory Air-Seed Shucker for Rapid
Quality Determinations of Chaffy Seed . . . . . C.L. Dewald
Agricultural Research Service, Woodward, OK;
A. Beisel
Aaron's Engineering, Fargo, OK

**Herbicide Application Equipment** . . . . . . . . . . . . . . .Ken Vahle
Warne Chemical Co., Rapid City, SD

**Disturbed Land Reclamation Workgroup** . . . . . . . . .Jim Smith
University of Wyoming, Laramie, WY
"Native" vs. "Exotic"—The Dilemma of Ecologically
Sound Mine Waste Revegetation. . . . . . Stuart A. Bengson
ASARCO, Inc., Sahuarita, AZ

**Panel Discussion:**
**Mines Reclamation**

Great Plains . . . . . . . . . . . . . . . . . . . . . . . . . Ed DePuitt
University of Wyoming, Laramie, WY

Intermountain . . . . . . . . . . . . . . . . . . . . . Eugene Farmer
Forest Service, Logan, UT

Arid Land . . . . . . . . . . . . . . . . . . . . . . . . . Earl Aldon
Forest Service, Albuquerque, NM

**Steep Slope Stabilization Workgroup** . . . . . . . . . Bob Hamner
Forest Service, Portland, OR

**Forest Service Equipment Development**
**Center Activities** . . . . . . . . . . . . . . . . . .Dan W. McKenzie
Forest Service, San Dimas, CA

**Information and Publications Workgroup**. . . .Dan W. McKenzie
Forest Service, San Dimas, CA

**General Critique—Open Discussion**

# Introductory Remarks

## The Changing Role of VREW in Rangeland Management

**Jack Bohning**, *Past President,*
*Society for Range Management,*
*Prescott, AZ*

VREW, as we know it today, came into being under the auspices of some very perceptive forebears. At its beginning back in 1945, those pioneers were responsible for farsighted recognition of specific needs in restoring productive capacity of western rangelands. The early efforts of that small group predated the formation of the Society for Range Management, but many of those same pioneers were active in the formation of both the Reseeding Equipment Development Committee and the American Society of Range Management. The "George Washington" of that era, Joe Pechanec, first chairman of the Equipment Development Committee and first president of the American Society of Range Management, is an outstanding example of "so few to whom we owe so much," to paraphrase Sir Winston.

The world—and the committee—have changed a great deal since those early days. This has produced a constantly evolving situation in which the members of the committee have become increasingly aware of burgeoning technologies providing opportunities for more and better interaction among various interests and disciplines. The horizons of the committee have broadened, and the diversity of the participants has increased tremendously. Therefore, the role of VREW needs to be redefined periodically to keep pace with the world.

Looking ahead, I see a continuing and expanding role for VREW. The need is there—the renewable and nonrenewable resources of 40 percent of the Earth's surface can only become more important as we see the world's population expanding at a terrific rate. Answering those needs—current and projected—presents an exciting challenge for members of VREW and the whole range management community.

Where are the roots of VREW? Subsequent to the historic 1945 brain-storming session, from 1946 to 1958 those ideas were pursued through the Reseeding Equipment Development Committee. Recognizing the inadequacy of existing equipment, they set themselves to modifying (or designing) equipment to meet specific needs in preparing and seeding rangeland. Their pragmatic approach gave us tools such as the rangeland drill and Ely chain, items that became bylines in range improvement work. It was the right approach for their time.

The evolutionary process was evidenced by a name change to the Range Seeding Equipment Committee, a name that served from 1958 to 1974. Things were happening behind that name change—approaches to problems were refined, more sophisticated mechanisms were developed for research and development. The influence of the committee was expanded; its role became more widely recognized and accepted. It was a period when the committee came of age and seriously began looking around at its place in the wide, wide world. This recognition of new areas of interest surfaced in renaming the committee in 1974, giving it its present name of the Vegetative Rehabilitation and Equipment Workshop.

More diverse participation was greatly encouraged when VREW's objective and mission were stated to be: "VREW is a forum to provide an exchange of ideas to enhance the development and dissemination of technology used in improving rangelands and surface-mined spoils." This objective statement is prominent in the history of VREW from 1946 to 1981, published in 1982. A maturing in the philosophy of range improvement work is strongly evident in the statement that to better identify an equipment project, VREW may promote an understanding of the ecology of the land to be treated as a first step in modifying or designing new equipment.

Close associations and working relationships between VREW and SRM were inevitable. As Ted Russell stated in the proceedings of the 1983 Albuquerque meeting, it is a "symbiotic relationship." Look at their histories—since 1951 most of the meetings of the two groups have been held jointly. There has always been an overlap of the people involved, many are long-time members of both. The SRM, with its diversity of membership and expertise, has provided the broad "generic" base for VREW and its predecessors which had inherently more specific involvement but with ties to the broader spectrum. It has been a happy marriage.

How does VREW work toward the objective stated earlier? What does it actually do to achieve its role of solving range improvement problems and then getting the word out? Here's how I see it:

First of all, and a prime factor in its success to date, VREW provides a catalyst for stimulating ideas and proposals from a wide array of sources. In responding to its objective, it provides a vehicle for publication of information with an in-place distribution net. For everyone interested in range improvement work, VREW provides a reference point, a "central library" to which they can refer. The programs of VREW reach out beyond the nation's borders through its publications; they provide a focal point for an international information exchange. VREW's history and roster of active participants attest to the fact that VREW benefits from continuity of participation. With its expanding horizons, VREW has become sought after as a partner by other groups with common interests such as the Mining and Reclamation Council and Office of Surface Mining. It gives the manufacturers of range improvement equipment and mine rehabilitation equipment an opportunity to display their offerings. And last but not least, there is the symbiotic relationship with the Society for Range Management.

Looking beyond today and the accomplishments of the past, what will affect the changing role of VREW in the future? I see several major factors which members of VREW should consider. First of all, there is a critical need for the continuing programs of VREW. The world's population continues its expansion, explosive in many areas. The need for more efficiently producing food, fiber and minerals will continue to grow. But meeting those needs is increasingly constrained by environmental concerns.

Despite short-term fluctuations, energy costs will increase over time. VREW needs to emphasize energy-efficiency in developing tools for range improvement and mine rehabilitation. The cost of labor—and its availability—will have an increasing impact on making improvements on rangeland, land which is relatively low in productivity compared to other areas competing for labor. This generates a need to optimize the labor requirement in rangeland improvement work.

Perhaps most critical of all, there is the need to sell rangeland and mine rehabilitation work as necessary for both economic and social benefits. We hear too often from the proponents of the "do nothing" alternative, not just to refrain from improvement work but to retreat from using our natural resources in favor of preservation. Here is the area where VREW and SRM must join forces to counter with positive information and demonstration—doing, showing and telling the story of proper use and management.

All these points add up to "challenge" for VREW. With the maturity that VREW has achieved, I am confident that it can meet the challenge and willingly accept the changing role of VREW in rangeland management.

# A Partner in Equipment Development

**Farnum M. Burbank,** *Mechanical Engineer*
*Equipment Development Group,*
*Washington Office*

During the past 35 years, several special interest groups have been associated with the Forest Service's Equipment Development Group, effectively using our skills for evaluating and developing unique equipment. Some groups functioned satisfactorily for a few years, then disbanded. However, one has persisted since 1946 and has proven its value year after year. Officially, this group does not exist; it is so loosely structured that it should not have survived; and it is so informal that there is no possibility of its achieving anything useful or being recognized for its contributions. Yet, the group's record of accomplishment during the past 37 years has been outstanding. I am describing the Vegetative Rehabilitation and Equipment Workshop (VREW), a true partner to Equipment Development.

### Origins

Back in 1946, some 15 to 20 range specialists got together to share their knowledge and exchange information about range seeding equipment. Recognizing the need for effective and suitable equipment, they decided to form a committee to tackle the problem. Within a short time, the group became known as the Range Seeding Equipment Committee.

When the American Society of Range Management (later, the Society for Range Management) was founded in 1948, the Range Seeding Equipment Committee began holding meetings just prior to and in the same location as the Society's annual meeting. Since many Equipment Committee participants were members of the Range Society, this scheduling stimulated attendance at both meetings, and this relationship has continued to this day.

Membership and participation grew and its composition varied over the years. In the Department of Agriculture, membership has included the Agricultural Research Service, Forest Service, Extension Service, Soil Conservation Service, and the Agricultural Stabilization and Conservation Service; in the Department of the Interior, it has included the Bureau of Land Managment, Bureau of Indian Affairs, Bureau of Reclamation, and the Fish and Wildlife Service. Representation has included various State agencies (fish and game departments, highway departments, and universities and other educational institutions); industrial representatives (chemical, equipment, mining, and seed companies); ranchers; and—more recently—environmental consultants. Many countries, including Australia, Canada, and Mexico, also have participated.

### Objectives and Activities

The broad objectives of the VREW have been to keep abreast of the field of commercially developed equipment, to make modifications as required for adaptation to wildland use, and to develop equipment not commercially available. Generally, the work can be described as evaluating commercially available equipment; identifying development needs; developing specifications and standards; arranging for construction; evaluating results; disseminating information; and implementing the successful equipment.

The Workshop is divided into a number of active workgroups that develop proposals, monitor project progress, assist in field testing, and report accomplishments. Names of these workgroups include Exploratory; Information and Publications; Seeding and Planting; Plant Materials; Seed Harvesting; Steep Slope Stabilization; Disturbed Land Reclamation; and Mechanical, Chemical, and Thermal Plant Control. Over the years, other workgroups have evolved as they were needed, operated as long as necessary, then disbanded.

The Forest Service Equipment Development Centers at San Dimas, Calif., and Missoula, Mont., normally handle project work on equipment development or evaluation activities. These professionally staffed engineering organizations were chartered by the Forest Service to help resource managers be more effective and efficient through mechanization and improved systems and techniques. This effort, however, is not limited to the Development Centers. Cooperative work is undertaken with private industry; research is conducted at universities; and trial projects and evaluations are being executed by field personnel.

The Forest Service, the Bureau of Land Management, and the Bureau of Indian Affairs provide most of the financial support. In addition, these agencies and other organizations also contribute considerable time and equipment to field testing and evaluation. Based on agency needs and priorities, specific project proposals may be financed through the Workshop. For private companies with identified needs for equipment development, there are procedures for cooperative financing.

### Equipment Developed

Before discussing our most recent activities, I would like to mention a few examples of equipment developed by the Range Seeding Equipment Committee. Most of this equipment was associated with range improvement work, which received heavy emphasis beginning in the midforties. One of the first items developed was the rangeland drill, which is still in demand. A version of a farm grain drill, this drill is very heavy and has independently sprung furrow arms for use on rough, irregular terrain. The brushland plow, a close second in popularity, is an adaptation of the Australian stump-jump plow, with each disk arm separately sprung for use in heavy brush. Each arm can lift over an obstruction without raising the entire plow. Contour trenching, which has been studied frequently, brought about such devices as modified front-end plows; a small Holt plow; the Rocky Mountain disk trencher; and a contour furrower that furrows, dams, seeds, and fertilizes in one operation.

In addition, the Committee has developed a great variety of seeders: the seed dribbler, interseeder, browse seeder, and various types of broadcast seeders. The collection of browse seed has long been a problem, and several attempts have been made to develop a device to collect a variety of seeds under adverse conditions. The Committee developed one truck-mounted piece of equipment, and we are still working on a backpack unit. Much activity has focused on control of sagebrush and other plant species, developments in aerial application equipment and techniques, and ground sprayers for chemicals. However, with the recent criticism surrounding the use of chemicals, greater emphasis has been placed on mechanical methods of brush control. We evaluated several types of brush cutters and crushers for various terrains and conditions, and we found thermal treatment useful in small areas for sagebrush and small conifer control. This list could go on, but these few examples show the great diversity of our endeavors and how they led us into even broader aspects of rehabilitation work.

### New Directions

In the early seventies, there was a rapidly growing interest in, and demand for, rehabilitation of disturbed lands—largely stemming from the environmental concerns connected with strip mining.

Because of our many years of experience in range improvement, we were suddenly called upon to help in related disturbed vegetation problems. It immediately became obvious that a new role was evolving for the Committee. Therefore, in 1973, the Committee changed its name to the Vegetative Rehabilitation and Equipment Workshop and instituted a new workgroup on Disturbed Land Reclamation. Since then, the overall program has become quite heavily oriented toward stabilization of disturbed lands, although project work continues on range improvement equipment.

Through equipment development efforts, the VREW produced a gouger that dispenses seeds as it builds basins; refined the Vermeer tree spade to transplant trees in rough terrain (as well as a transporter to make the operation economically feasible); evaluated the Howard rotavator for mixing additives; modified a commercial manure spreader to dispense hay; built a new basin blade and a plug planter; and developed a large sod mover. Smaller, more localized devices also have been developed for disturbed land operations.

### Conclusion

In summary, the VREW has been a true partnership between resource managers and engineers in equipment development. As mentioned earlier, it has been an informal group—no charter, bylaws, or direction by a single agency; yet, the results have been significant. Perhaps the cooperative spirit engendered by the Workshop is as important as any of its achievements. It is a classic example of what can be accomplished if no one is too concerned about who gets the credit!

# Panel Discussions

## Chemical, Thermal, and Mechanical Control of Noxious Weeds--Progress and Prognosis

### Introduction

**Russell J. Lorenz,** *Panel Moderator; Agricultural Research Service, Mandan, ND*

Leafy spurge (*Euphorbia esula* L., *E. virgata* Waldst. & Kit, and closely related *Euphorbia* species) is an introduced weed that has become a major problem in the United States and Canada, particularly on rangelands in the northern Great Plains. Consequently the panel speakers will address the topic primarily in terms of leafy spurge. The same general principles will apply to other perennial weedy forb problems given some fine tuning for the specific problem. Hopefully, we have learned a lesson from leafy spurge in that we will be more vigilant and aggressive in attacking other perennial weeds, particularly those introduced during early settlement of the United States and Canada.

Leafy spurge infests millions of acres and causes millions of dollars in economic loss. Leafy spurge occurs in more than 30 States and in all Canadian Provinces; however, more than 90 percent of the leafy spurge on the North American Continent is found in a 1,200-mile-diameter circle centered on Wolf Point, MT. To help you understand how this came to be, I'll give you some background on leafy spurge.

Leafy spurge is widespread in continental Europe and Asia, extending from central Spain eastward through central Russia and Siberia. It is of little economic or agronomic significance in most of this extensive area primarily because more than 100 insects and diseases are specific predators on the *Euphorbia* complex we know as leafy spurge. The panel following this one will address biological control in detail. At this point it is sufficient to say the colonists and early settlers brought weed seeds along with their crop seeds, but failed to bring the insect and disease predators. Native North American insects and diseases seldom use leafy spurge as a host.

Of major importance is the fact that several species of leafy spurge exist in Europe and Asia and that multiple introductions to North America occurred. Consequently, a very diverse and complex population of leafy spurge developed as it spread from its many points of introduction. For example, it is unlikely that leafy spurge spread westward to the Plains from the stands found in Massachusetts in 1827. Certainly there has been some natural spreading from the sites of the first stands in the colonial States, but it appears that the rapid western movement was primarily in crop seeds carried by the settlers from their homelands. These people were not concerned about leafy spurge seed or the dozens of other species of weed seed that they were carrying with them. In most cases these weeds were not a serious problem in their native countries. Without natural predators, leafy spurge and other weeds found a particularly favorable environment in the northern Great Plains of the United States and the Prairie Provinces of Canada.

Evidence of the widespread introduction of leafy spurge can be found in the hundreds of references to leafy spurge that United States and Canadian botanists and others made in their writing during the hundred years preceding 1935. Several early writers recognized it as a potential problem. In the first addition of his Manual in 1848, Asa Gray referred to leafy spurge as a weed that was likely to become troublesome. Landowners in general were not aware of these warnings, or if they knew of them, they ignored both the warnings and the weed. It became troublesome in cropland first because that is where it was being seeded. Some of the early weed control work by the newly organized State experiment stations dealt with leafy spurge control in cropland. With the development and use of herbicides, leafy spurge was held in check on cropland. However, it was often allowed to occupy waste places or small spots on the farm because it was not really taking much land out of production. Its strong, deep and spreading root system and prolific seed production made it a very difficult weed to control.

The failure to recognize the potential problem at the spot-here-and-there stage led to leafy spurge invasions of grasslands, wooded areas, and other uncultivated land. Birds, wind, and water helped spread the seed to inexcessible places. The widespread distribution of seed producing plants led to the virtual explosion of leafy spurge in the 1970's. Unusually dry weather in May and June in the early 1980's resulted in a leafy spurge explosion in much of the northern Great Plains. Normally the cool-season grasses provide a lot of competition for developing seedlings early in the spring. Without this competition, many new leafy spurge plants became established.

During the past 15 years a number of concerned farmers, ranchers, land managers, educators, and scientists have tried to bring public attention to the insideous leafy spurge problem. The social-economic impact of leafy spurge was recognized as a very serious problem only in local communities in which heavy infestations occurred. It rapidly became serious on a national basis as more and more of the most productive grasslands in the Nation were invaded. It became of international concern with heavy infestations on both sides of the U.S.-Canadian border.

The first organized effort by those concerned was to establish a steering committee, which organized the Leafy Spurge Symposium held in Bismarck, ND, June 26-27, 1979. The symposium was well attended and consequently was very successful. It outlined the leafy spurge problem, summarized all known information on leafy spurge, and identified research and extension needs. The proceedings were published and widely distributed. Following the symposium, a committee

was established to prepare a research project request to the Old West Regional Commission involving the five Old Western Regional Commission States. A project entitled "Leafy Spurge Control Using Integrated Management Systems" was approved and funded for the period March 1, 1981 to February 28, 1982.

On December 17-18, 1979, a followup to the Bismarck symposium was held in Billings, MT. The Billings conference was planned to provide the impetus for the next step toward an active research, extension, and coordinated control program. The objective of providing an action-oriented program was met by the conference. The proceedings of this conference have also received wide distribution. A pro tem steering committee was named at the conference to insure that the momentum gathered to this point was not lost. One of its actions was to appoint a Leafy Spurge Working Committee charged with preparation of a specific program package covering three major areas: research, extension/education, and coordinated control.

The working committee report had input from North Dakota, South Dakota, Nebraska, Montana, and Wyoming, and it laid the groundwork for cooperative work with Canada. It was distributed to legislators, administrators, and policymakers at Federal, State, and local levels. The working committee also prepared a proposal to the Great Plains Agricultural Council requesting that a Great Plains Coordinating (GPC) Committee be established to insure continuity to the program after the steering committee and working committee were disbanded. A pre-organizational meeting of the GPC committee was held in Fargo, ND, in January 1981, and the committee was approved by the GPAC during its meeting in Garden City, KS, June 9-11, 1981. The first annual meeting of the new GPC-14 committee was held June 29-30, 1981 in Fargo. Subsequent meetings were held in Bozeman, MT, June 21-22, 1982 and Sundance, WY, June 21-22, 1983. The 1984 meeting will be in Dickinson, ND, June 26-28.

It is true that committees and meetings do not kill weeds. However, the urgency of the problem and the extremely limited resources in each State and Province necessitated a coordinated approach in order to put together the best possible technology in the shortest possible time. We do not have all the answers, but I believe that this approach has been very successful in advancing the control of leafy spurge. It could also be applied to other weeds.

Chemical and cultural control are relatively effective on cropland. However, it is another matter on grasslands. Cattle will not graze leafy spurge. Work in Montana indicates that it is of some use to sheep. Cultural control on grassland is limited to mowing where possible, but most rangeland is too rough and inaccessible to make this a viable treatment. At best, mowing prevents seed production. It does not have much affect on the extensive root system or on its competitiveness with other species. Burning is also of questionable value in terms of effectiveness of control and of even more questionable feasibility on many sites. That leaves chemicals as the best technology to date.

The effective chemicals are costly and consequently are of questionable economic practicality on land of relatively low value. However, recent research on the physiology, phenology, taxonomy, and morphology of leafy spurge is helping us understand the weak points of this complex plant. This in turn is helping reduce the amount of chemical needed to attain given levels of control. Consequently it is reducing the cost of control.

No single research or extension group has received enough funding to carry on an independent program that would in itself be effective. However, by redirecting resources and by coordinating efforts between Federal, State, and Provincial units, sizable gains have been made in control technology. The coordinated integrated control efforts have been facilitated by legislation, authorization, and implementation of weed control laws, including mil levies and appointment of county weed officers and boards to help landowners coordinate their control efforts.

The panel members will address specific chemical, thermal, and mechanical control practices, and the following panel will address the biological control possibilities. It is my firm belief that it will be through a combination of all of these control practices that most of our noxious weeds will be controlled and that we cannot afford to wait for the perfect technology before we begin control. We need to proceed posthaste using the best technology at hand.

## Leafy Spurge on the Northern High Plains—Characteristics, Site Requirements, and Concerns

**Ardell J. Bjugstad,** *Forest Service, Rapid City, SD*

Leafy spurge (*Euphorbia esula* L.) is a herbaceous deep-rooted perennial of the spurge (*Euphorbiaceae*) family (Messersmith 1983). Leaves are simple linear to oblong and have milky sap, which is typical of the spurge family. The spurge family is large, including the poinsettia (*Poinsettia dentata*) and castor-oil plant (*Ricinus communis*), often grown as an ornamental. All wild members of this family in the northern High Plains belong to the genus *Euphorbia*.

The depth and longevity of the root system has made this plant very persistent. The root system has the capability of producing new shoots from various depths and from mere fragments of roots. Root systems, with no mortality, have lived 6 years during the development of the plant.

The seeds are about the size and shape of pearl millet—2 to 2.5 mm long. This makes them attractive to large and small birds—such as the sharptailed grouse (*Pedioecetes phasianellus*) and field sparrows (*Spizella pusilla*). One sharptail grouse dropping collected near an extensive infestation of leafy spurge contained 490 seeds with 200 seeds identified as leafy spurge. Of the 490 seeds, 51 germinated and 2 were leafy spurge. Birds are considered primary disseminators of spurge seed.

Lowland range sites and bottomland topographical positions on the northern High Plains have been described as actual or potential prairie woodland sites. They have recently been described as sites where leafy spurge dominates over other herbaceous vegetation in the community. Efforts to control the noxious weed with chemicals will also effect hardwood species on these sites or prohibit regeneration of hardwood species. These data suggest management closely monitor lowland and sandy range sites for infestations of leafy spurge and immediately instigate control efforts at initial infestation.

## Evaluation of Original and Repetitive Herbicide Treatments for Control of Leafy Spurge

**Harold P. Alley,** *University of Wyoming, Laramie, WY*

Leafy spurge (*Euphorbia esula* L.) is a competitive and aggressive perennial that is very difficult and expensive to control. Its deep tenacious root system, with the capacity to sprout from root segments and underground buds, along with the potential of the seed remaining viable for up to 8 years is indicative of its persistent nature.

The weed has spread in recent years from small isolated areas to where it is reported to infest 2.5 million acres in the United States and Canada. It is found from the best agriculture land to rocky slopes and hillsides of low productive rangeland sites. Infestations range from solid stands where all other vegetation is virtually eliminated to isolated infestations that serve as a source of seed for spread and subsequent infestation of additional areas.

An extensive repetitive herbicide treatment program for leafy spurge control was initiated in 1978, and the effect of original and retreatments on leafy spurge shoot and root control has been evaluated since the initiation of the study.

The initial herbicide treatments were made on May 25, 1978, and included dicamba (3,5-dichloro-o-anisic acid) at 4.0 and 8.0 lb ai/A, picloram (4-amino-3,5,6-trichloropicolinic acid) at 0.5, 1.0 and 2.0 lb ai/A of the K salt and 2 percent bead formulation, picloram/2,4-D amine (1.0 lb picolinic acid + 2,4-D amine/gal) at 0.5 + 1.0, 1.0 + 2.0 and 2.0 + 4.0 lb ai/A and an untreated check.

The herbicides included in the retreatment program were: dicamba at 2.0 lb ai/A, dicamba/2,4-D amine at 1.0 + 2.0 lb ai/A, 2,4-D amine at 2.0 lb ai/A, and picloram (Tordon 22K) at 0.5 and 1.0 lb ai/A.

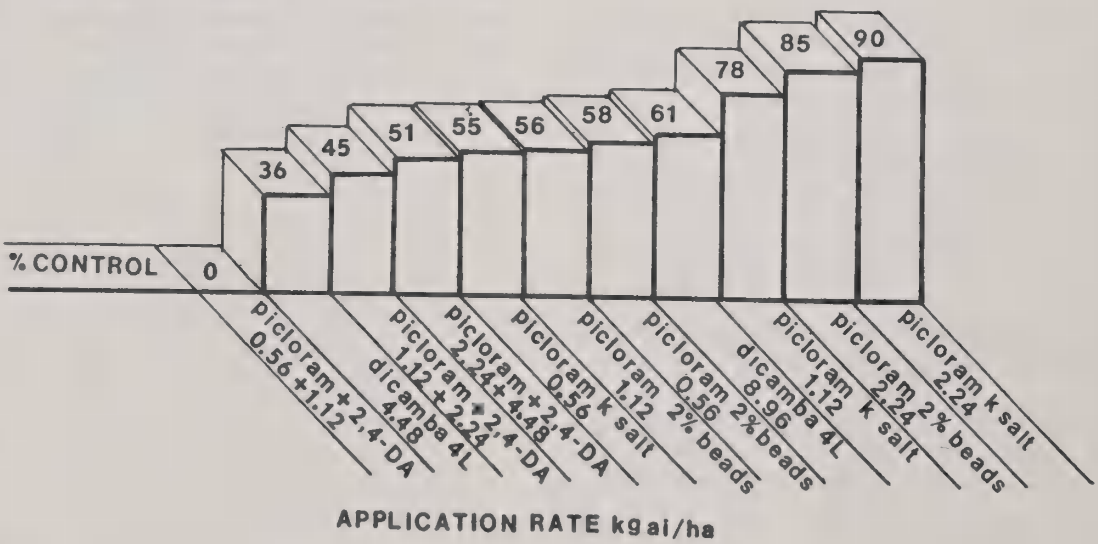


Figure 1.—Longevity of leafy spurge shoot control resulting from treatments applied in 1978 and evaluated in 1982.

The retreatments have been applied each year since the initiation of the program. However, due to the near complete control of the leafy spurge shoot growth, the retreatment with Tordon 22K was terminated with the 1981 application.

The percentage leafy spurge shoot control resulting from the original treatments through 1982 is presented in figure 1 and through 1982 in table 1. The original treatment of picloram K salt and 2 percent beads applied at the rate of 2.0 lb ai/A in 1978 were maintaining 68 to 74 percent leafy spurge shoot control, respectively, 5 years following treatment. This is a decrease in about 10 percentage points in the last year and follows the general trend of from 3 to 10 percentage points each succeeding year.

Table 1.—*Percentage leafy spurge shoot control resulting from the original and three successive herbicide retreatments*

| Original Treatments[1] (lb ai/A) | Percent Shoot Control Retreatment lb ai/A: 2,4-D amine 2.0 | | | | picloram (K salt) 0.5 | | | | picloram (K salt) 1.0 | | | | dicamba 4L 2.0 | | | | dicamba/2,4-D amine 1.0 + 2.0 | | | | Check | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1980 | '81 | '82 | '83 | 1980 | '81 | '82 | '83 | 1980 | '81 | '82 | '83 | 1980 | '81 | '82 | '83 | 1980 | '81 | '82 | '83 | 1979 | 1980 | 1981 | 1982 | 1983 |
| picloram (K salt) 2.0 | 98 | 93 | 94 | 99 | 99 | 100 | 100 | 99 | 99 | 100 | 100 | 100 | 98 | 96 | 97 | 97 | 99 | 95 | 98 | 98 | 99 | 96 | 90 | 90 | 68 |
| picloram (K salt) 1.0 | 76 | 84 | 83 | 86 | 96 | 99 | 99 | 86 | 99 | 100 | 100 | 100 | 96 | 90 | 96 | 95 | 99 | 89 | 98 | 94 | 97 | 94 | 84 | 78 | 80 |
| picloram (K salt) 0.5 | 70 | 80 | 86 | 88 | 94 | 99 | 98 | 88 | 99 | 100 | 100 | 100 | 49 | 79 | 88 | 84 | 59 | 77 | 85 | 70 | 76 | 43 | 29 | 55 | 24 |
| picloram (2% beads) 2.0 | 90 | 90 | 87 | 92 | 98 | 99 | 99 | 92 | 100 | 100 | 100 | 100 | 96 | 98 | 96 | 99 | 96 | 87 | 98 | 98 | 99 | 95 | 83 | 85 | 74 |
| picloram (2% beads) 1.0 | 84 | 92 | 86 | 92 | 99 | 99 | 99 | 92 | 98 | 99 | 100 | 100 | 87 | 82 | 96 | 89 | 65 | 82 | 88 | 87 | 96 | 51 | 68 | 55 | 67 |
| picloram (2% beads) 0.5 | 78 | 76 | 76 | 84 | 99 | 100 | 99 | 84 | 99 | 100 | 100 | 100 | 69 | 77 | 79 | 84 | 64 | 78 | 91 | 79 | 87 | 32 | 36 | 58 | 31 |
| picloram/ 2,4-D amine 2.0 + 4.0 | 81 | 90 | 88 | 98 | 99 | 99 | 98 | 98 | 100 | 100 | 100 | 100 | 99 | 95 | 96 | 99 | 78 | 89 | 94 | 85 | 98 | 91 | 87 | 51 | 37 |
| picloram/ 2,4-D amine 1.0 + 2.0 | 63 | 76 | 81 | 81 | 96 | 98 | 98 | 81 | 100 | 100 | 100 | 100 | 68 | 89 | 94 | 90 | 39 | 64 | 91 | 80 | 71 | 38 | 31 | 45 | 35 |
| picloram/ 2,4-D amine 0.5 + 1.0 | 58 | 66 | 76 | 66 | 97 | 96 | 98 | 66 | 99 | 100 | 100 | 100 | 49 | 65 | 84 | 87 | 40 | 73 | 88 | 89 | 16 | 0 | 0 | 0 | 7 |
| dicamba 4L 8.0 | 74 | 82 | 87 | 83 | 87 | 96 | 98 | 83 | 98 | [illegible] | 100 | 94 | 89 | 87 | 96 | 98 | 78 | 94 | 98 | 97 | 67 | 66 | 77 | 61 | 50 |
| dicamba 4L 4.0 | 53 | 69 | 78 | 78 | 84 | 97 | 98 | 78 | 100 | 100 | 100 | 100 | 67 | 84 | [illegible] | 81 | 56 | 83 | 90 | 90 | 47 | 42 | 24 | 36 | 28 |
| Check | 9 | 58 | 62 | 78 | 96 | 99 | 97 | 78 | 93 | 100 | 100 | 100 | 72 | 85 | 92 | 95 | 11 | 63 | 84 | 66 | 11.6 | 11.1 | 11.4 | 13.9 | |

[1]Original treatments May 25, 1978; retreatments June 21, 1979, May 13, 1980, May 20, 1981, and May 19 1982; evaluated in 1979 through 1983. Retreatments of Tordon 22K at 0.5 and 1.0 lb ai/A terminated with 1981 treatments.

The effectiveness of the various original treatments which received the different repetitive treatments are presented in tables 2 through 7. The most consistent and effective original plus repetitive treatment was where picloram was a component of each of the treatments. Picloram applied at 0.5 lb ai/A in 1978 and retreated in 1979, 1980, and 1981 with 0.5 lb ai/A was maintaining 98 and 99 percent shoot control, respectively, for the K salt and 2 percent bead formulations. Where high rates of the initial treatment were applied and retreated with the 0.5 lb ai/A rate of the liquid formulation, shoot control ranges from 98 to 100 percent.

Picloram as an original treatment and retreated four successive years with dicamba, dicamba/2,4-DA, or 2,4-DA were not as effective, especially at the lower rates of picloram (table 3).

Outstanding leafy spurge shoot control can be obtained with dicamba if the retreatment program is picloram (table 4). The higher rates of dicamba required as an original treatment are not as effective as lower rates of picloram and are considerably more damaging to the associated vegetation.

Data indicate that a maintenance or repetitive herbicide treatment program would not have to be initiated for 3 years where 2.0 lb ai/A of picolinic acid was utilized. Also an effective control program is feasible with low rates of picloram as an original treatment if a retreatment program is carried out.

Preliminary investigation using a mechanical removal (mowing) of leafy spurge vegetative growth prior to herbicide treatment looks promising where such a program could be utilized.

Plots were mowed and approximately 3 weeks later picloram, 2,4-D, and dicamba were applied to the regrowth. There appeared to be no difference between 0.5 lb ai/A of picloram and 1.0 lb ai/A of 2,4-DLVE. Evaluated 1 year following treatment the shoot control was 86 and 91 percent, respectively, for the picloram and 2,4-D treatment (table 8).

Another interesting study initiated in 1982 was the use of light rates of 2,4-DLVE as a set-up for the application of reasonably low rates of picloram. Leafy spurge shoot counts made 1 year following treatment shows 100 percent control where the various combinations were used (table 9).

Table 2.—*Percentage leafy spurge shoot control resulting from picloram as the original treatment and picloram as a retreatment.*

| Original treatment[1] | Retreatment[2] Rate lb ai/A: picloram 0.5 | | | | picloram 1.0 | | | |
|---|---|---|---|---|---|---|---|---|
| | 1980 | 1981 | 1982 | 1983 | 1980 | 1981 | 1982 | 1983 |
| picloram 0.5 | 94 | 99 | 98 | 93 | 99 | 100 | 100 | 100 |
| picloram 1.0 | 96 | 99 | 99 | 98 | 99 | 100 | 100 | 100 |
| picloram 2.0 | 99 | 100 | 100 | 100 | 99 | 100 | 100 | 100 |

[1]Original treatment: 1978.
[2]Retreatments: 1979, 1980, 1981.

Table 3.—*Percentage leafy spurge shoot control resulting from picloram as the original treatment and dicamba, dicamba/2,4-DA, and 2,4-DA as a retreatment*

| Original treatment[1] | Retreatment[2] Rate lb ai/A: dicamba 2.0 | | | | dicamba/2,4-DA 1.0 + 2.0 | | | | 2,4-DA 2.0 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1980 | 1981 | 1982 | 1983 | 1980 | 1981 | 1982 | 1983 | 1980 | 1981 | 1982 | 1983 |
| picloram 0.5 | 49 | 79 | 88 | 84 | 59 | 77 | 85 | 70 | 70 | 80 | 86 | 88 |
| picloram 1.0 | 96 | 90 | 96 | 95 | 99 | 89 | 98 | 94 | 76 | 84 | 83 | 86 |
| picloram 2.0 | 98 | 96 | 97 | 97 | 99 | 95 | 98 | 98 | 98 | 98 | 94 | 99 |

[1]Original treatment: 1978.
[2]Retreatments: 1979, 1980, 1981, 1982.

Table 4.—*Percentage leafy spurge shoot control resulting from dicamba as the original treatment and picloram as a retreatment*

| Original treatment[1] | Retreatment[2] Rate lb ai/A picloram 0.5 1980 | 1981 | 1982 | 1983 | picloram 1.0 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|---|
| dicamba 4.0 | 84 | 97 | 98 | 85 | 100 | 100 | 100 | 100 |
| dicamba 8.0 | 87 | 96 | 98 | 93 | 98 | 98 | 100 | 94 |

[1]Original treatment: 1978.

[2]Retreatments: 1979, 1980, 1981, 1982.

Table 5.—*Percentage leafy spurge shoot control resulting from dicamba as the original treatment and dicamba, dicamba/2,4-DA, and 2,4-DA as a retreatment*

| Original treatment[1] | Retreatment[2] Rate lb ai/A dicamba 2.0 1980 | 1981 | 1982 | 1983 | dicamba/2,4-DA 1.0 + 2.0 1980 | 1981 | 1982 | 1983 | 2,4-DA 2.0 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dicamba 4.0 | 67 | 84 | 88 | 81 | 56 | 83 | 90 | 90 | 53 | 69 | 78 | 78 |
| dicamba 8.0 | 87 | 87 | 96 | 98 | 78 | 94 | 98 | 97 | 74 | 82 | 87 | 83 |

[1]Original treatment: 1978.

[2]Retreatments: 1979, 1980, 1981, 1982.

Table 6.—*Percentage leafy spurge shoot control resulting from picloram/2,4-DA as the original treatment and picloram as a retreatment*

| Original treatment[1] | Retreatment[2] Rate lb ai/A picloram 0.5 1980 | 1981 | 1982 | 1983 | picloram 1.0 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|---|
| picloram/2,4-D 0.5 + 1.0 | 97 | 96 | 98 | 94 | 99 | 100 | 100 | 100 |
| picloram/2,4-D 1.0 + 2.0 | 96 | 98 | 98 | 98 | 100 | 100 | 100 | 100 |
| picloram/2,4-D 2.0 + 4.0 | 99 | 99 | 98 | 100 | 100 | 100 | 100 | 100 |

[1]Original treatment: 1978.

[2]Retreatments: 1979, 1980, 1981, 1982.

Table 7.—*Percentage leafy spurge shoot control resulting from picloram/2,4-DA as the original treatment and dicamba, dicamba/2,4-DA and 2,4-DA as a retreatment*

| Original treatment[1] | Retreatment[2] Rate lb ai/A dicamba 2.0 1980 | 1981 | 1982 | 1983 | dicamba/2,4-DA 1.0 + 2.0 1980 | 1981 | 1982 | 1983 | 2,4-DA 2.0 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| picloram/2,4-DA 0.5 + 1.0 | 49 | 65 | 84 | 87 | 40 | 73 | 88 | 89 | 58 | 66 | 75 | 66 |
| picloram/2,4-DA 1.0 + 2.0 | 68 | 89 | 94 | 90 | 34 | 64 | 91 | 90 | 63 | 76 | 81 | 81 |
| picloram/2,4-DA 2.0 + 4.0 | 99 | 95 | 96 | 99 | 78 | 89 | 94 | 85 | 81 | 90 | 88 | 98 |

[1]Original treatment: 1978.

[2]Retreatments: 1979, 1980, 1981, 1982.

Table 8.—*Evaluation of mowing as a set-up treatment prior to herbicide application for leafy spurge shoot control*

| Treatment[1] | Rate lb ai/A | Percent Shoot Control[2] |
|---|---|---|
| dicamba 4L | 1.0 | 32 |
| picloram | 0.5 | 86 |
| 2,4-D LVE | 1.0 | 91 |
| shoot/ft$^2$ | | 23.2 |

[1]Plots mowed June 30, 1982; treatments applied July 21, 1982.
[2]Shoot counts May 19, 1983.

Table 9.—*Evaluation of 2,4-D LVE as a pretreatment prior to light rates of picloram for leafy spurge shoot control*

| Treatment[1] | Rate (lb ai/A) | Percent Shoot Control[2] |
|---|---|---|
| 1 Day Set-up 2,4-D LVE | | |
| 2,4-D LVE/Tordon 22K | 0.0625 + 0.5 | 100 |
| " " | 0.125 + 0.5 | 100 |
| " " | 0.25 + 0.5 | 100 |
| " " | 0.0625 + 1.0 | 100 |
| " " | 0.125 + 1.0 | 100 |
| " " | 0.25 + 1.0 | 100 |
| 17 Day Set-up 2,4-D LVE | | |
| 2,4-D LVE/Tordon 22K | 0.0625 + 0.5 | 100 |
| " " | 0.125 + 0.5 | 100 |
| " " | 0.25 + 0.5 | 100 |
| " " | 0.0625 + 1.0 | 100 |
| " " | 0.125 + 1.0 | 100 |
| " " | 0.25 + 1.0 | 100 |

[1]Plots treated with 2,4-D LVE 1 and 14 days prior to treatment with Tordon 22K. 1982.
[2]Shoot counts May 18, 1983.

## Chemical Control of Leafy Spurge and Other Perennial Weeds in North Dakota Pastures

**Calvin G. Messersmith and Rodney G. Lym,**
*North Dakota State University, Fargo, ND*

Leafy spurge (*Euphorbia esula* L.) topgrowth can be controlled with 2,4-D, but control in terms of density reduction usually is less than 40 percent (table 1). Other experiments with repeat treatments of 2,4-D indicate that only modest improvements in leafy spurge control will occur, and it seems unlikely that eradication is possible even after several years of annual or twice per year (spring and fall) treatments. The 2,4-D amine and ester formulations provide similar control when evaluated 12 months after treatment (data not shown). Dicamba at 2 lb/A or less generally is similar in effectiveness to 2,4-D for leafy spurge control and is a more expensive treatment than 2,4-D (table 1). Dicamba at 4 to 8 lb/A can provide 60 to 80 percent control at 12 months, but usually there is substantial stand reestablishment by 24 to 36 months after treatment.

Table 1.—*A summary of leafy spurge control 12 months after application for herbicide treatments applied in many different experiments over a 20-year period*

| Herbicide | Rate (lb/A) | Control (%) |
|---|---|---|
| 2,4-D | 1 | 8 |
| 2,4-D | 2 | 38 |
| Dicamba | 1 | 10 |
| Dicamba | 2 | 21 |
| Dicamba | 4 | 64 |
| Dicamba | 8 | 80 |
| Picloram | 0.25 | 30 |
| Picloram | 0.5 | 63 |
| Picloram | 1 | 74 |
| Picloram | 2 | 96 |
| Picloram + 2,4-D | 0.25 + 1 | 64 |
| Picloram + 2,4-D | 0.5 + 1 | 87 |
| Glyphosate (fall applied) | 0.75 | 78 |
| Glyphosate (fall applied) | 1 | 66 |
| Glyphosate (fall applied) | 2 | 91 |

Picloram is the most effective herbicide for leafy spurge control (table 1). Picloram at 0.25 to 0.5 lb/A usually provides more leafy spurge control than 2,4-D or low dicamba rates, but annual repeat treatments are required for substantial stand reduction. Picloram at 1 to 2 lb/A provides the best initial stand reduction, but a followup treatment often is required depending upon the picloram rate used and the initial control obtained. A combination of picloram at 0.25 to 0.5 lb/A plus 2,4-D at 1 lb/A is synergistic over either herbicide used alone, but repeat treatment will be required to maintain good leafy spurge control. The picloram plus 2,4-D

combination is less expensive than picloram alone for a comparable level of leafy spurge control. An advantage for including 2,4-D in the mixture has not been obtained when the picloram rate is 1 lb/A or more.

Glyphosate at 0.75 lb/A provides good leafy spurge control when fall applied (table 1). However, it is a nonselective herbicide that controls desirable forage and does not have a soil residual, so a followup herbicide treatment to control leafy spurge seedlings the next year is essential. Thus, glyphosate use is limited to areas, such as under trees, where a residual herbicide may be injurious.

Herbicide treatments to control leafy spurge resulted in improved forage production (table 2). Forage yield was increased at least 50 percent for most herbicide treatments and forage yield more than doubled for some treatments. Treatment programs that began with picloram at 2 lb/A provided the best long-term leafy spurge control, but the net income was negative due to the high cost of picloram. A treatment program based on using relatively inexpensive treatments such as 2,4-D only or picloram at 0.25 lb/A plus 2,4-D at 1 lb/A provided a positive net income. However, the treatments that provided a positive net income must be repeated annually for at least 3 to 5 years, because the leafy spurge control 12 months after treatment is comparatively low.

The effectiveness of a postemergence herbicide on leafy spurge is affected by the timing of herbicide application. The first optimum time for herbicide application to obtain maximum control is during the seed filling and maturation stage, which occurs from late June through early July. Leafy spurge control is substantially reduced compared to late June treatment when herbicide application is made when the first yellow sub-floral bracts appear in late May through early June. The second optimum time for herbicide application is late August through mid-September after leafy spurge has resumed vegetative development following rainfall and cooler temperatures that occur in mid- to late August. Translocation of carbohydrate content of roots increases during cool periods and decreases during warm periods. In theory, herbicide translocation to the roots would increase during cool periods, and experiments are being conducted to evaluate this theory.

Broadcast application of picloram often results in a negative net income of forage production compared to treatment costs, so selective applicators have been used to reduce the amount of picloram applied. Selective applicators have included the roller and pipe-wick equipment that treat mostly the tall leafy spurge without rubbing much of the grass. Herbicide application has been reduced by 50 to 70 percent in dense leafy spurge stands. Leafy spurge control has been equivalent to or better than picloram at 1 lb/A broadcast in several experiments, but results have been unacceptable in several other experiments. Generally, fall application has been more consistent than spring treatment. Treatment parameters to provide consistent control must be determined before this is a viable application alternative in many cases.

Other rangeland weeds that have been controlled include western snowberry (*Symphoricarpos occidentalis* Hook.) and absinth wormwood (*Artemisia absinthium* L.). Western snowberry was controlled most effectively by 2,4-D at 1.5 lb/A with 98 percent control of emerged stems and only 11 percent regrowth of shoots from roots 12 months after treatment. Picloram and dicamba generally provided less than 10 percent control of western snowberry. Glyphosate at 0.5 lb/A provided 98 percent control of western snowberry, but the nonselective characteristics of glyphosate limit the places where it could be used. Dicamba at 1.12 lb/A and 2,4-D at 2.24 lb/A provided approximately 80 percent control of absinth wormwood 12 months after treatment. However, picloram at 0.12 and 0.19 lb/A provided 89 and 99 percent absinth wormwood control, respectively, and generally the herbicide costs would be less than the 2,4-D and dicamba treatments.

Table 2.—*Effects of annual herbicide treatment 1980-83 on leafy spurge control, forage production, and net income through 1983*

| Treatment 1980 Herbicide | 1980 Rate (lb/A) | Treatment 1981-1982-1983 Herbicide | 1981-1982-1983 Rate (lb/A) | Leafy spurge control (%) | Forage yield (avg/yr) (lb/A) | Total net income 1980-83 ($/A) |
|---|---|---|---|---|---|---|
| Control | — | Control | — | 0 | 968 | 0 |
| Picloram | 2 | Dicamba | 2 | 89 | 1440 | -106 |
| Picloram | 2 | Picloram | 0.25 | 87 | 1511 | - 70 |
| Picloram | 2 | 2,4-D | 1 | 84 | 1400 | - 54 |
| — | — | Picloram + 2,4-D | 0.25 + 1 | 38 | 2125 | 41 |
| 2,4-D | 2 | 2,4-D | 1 | 14 | 1794 | 50 |

# Biological Control of Noxious Weeds--Progress and Prognosis

## Introduction

**Lloyd A. Andres,** *Panel Moderator;*
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Although the title of this panel is "progress and prognosis" of biological control, it is probably more appropriate to refer to many of the developments in biological control as changes rather than progress. A number of these changes have lengthened and made more difficult the test and clearance procedures, although I feel we are now closer to adequately evaluating and eventually releasing safe natural enemies against some of our major weeds than ever before.

I wish to describe some of the ideas underlying the practice of biological control and the steps and procedures followed in selecting weed projects and the development of biological control, primarily as it pertains to range problems.

**How biological control works:** It is now generally recognized that weed populations can be regulated by insects, plant pathogens, and other organisms that may parasitize or feed upon them. This regulating action may be quite rapid and dramatic at some sites (e.g., *Hypericum perforatum,* California; *Opuntia* spp., Australia; *Senecio jacobaea,* California), but limited at others. In part, this variable response is due to the complexity of the ecosystem and the myriad of interactions that take place between the environment, the weed plant, and the natural enemies. Where weed growth conditions remain near optimum and the plant suffers little if any stress, the weeds are often able to overcome most biological control agents. On the other hand, in habitats of high environmental stress, good control can be obtained with just a single natural enemy species. The inability of biological control workers to measure or equate the stresses of one habitat to the next, or to select those candidate natural enemies that may best complement existing environmental stresses, will always leave the outcome of a project in doubt even when using the same natural enemy against the same weed.

**Manipulating natural enemies:** The concept of manipulating already existing organisms to control native weeds received some early attention, but it wasn't until the discovery and development of an indigenous pathogen attacking northern jointvetch, a weed in rice fields of Arkansas and Louisiana, that the manipulative approach was shown to be practical. In this particular case, the pathogen was cultivated and reapplied to the weedy plant early in the growing season, eventually producing 90 to 95 percent control. Since the initial project, a number of pathogens on native as well as naturalized weeds have been recognized and are being studied for their control potential. Most of these efforts are being directed toward cropland weeds. Whether indigenous pathogens can be found that will prove of practical value on rangeland weeds remains untested.

**Introducing natural enemies:** Most weed biological control efforts have centered around finding and testing the natural enemies of introduced weeds in areas of the world where they coevolved with their host plants. As with any introduction of a living organism into a new environment, great care is taken that the weed control candidate organisms will not appreciably damage other plants of recognized value. A protocol has developed to offer some assurance that the most appropriate weed control candidates are found and adequately tested before their introduction into new areas. Early workers proceeded with few, if any, tests prior to introduction, but as people became aware of the impact that introduced organisms can have on plants, tests and testing procedures became more stringent. The time required to clear a weed-feeding insect may run up to 5 years, and even longer in difficult cases. Some of the steps and procedures to introducing new agents include:

1. *Selecting the project weed:* Key considerations include: (a) best available economic loss data on the weed; (b) analysis as to the origin and cause of the problem and whether the causes can be corrected; (c) noting the close economic and ecological relatives of the weed to determine just how specific the candidate organism must be to meet United States clearance requirements; (d) characterization of the weed's life cycle and habitat in which it occurs; (e) alternative methods of control available; (f) accessibility to the native ranges of the target weed to collect natural enemies; and (g) whether there are a substantial number of domestic project supporters and cooperators. Biological control workers need the assistance of range managers, farmers, and State and Federal workers in getting this data.

2. *Proper weed identification:* Many plant natural enemies are extremely host specific, so much so that if they are collected from a biotype of the target weed different from that which exists in the United States, they will not establish on the weed once released. Properly identifying and pinpointing the origin of the U.S. weed are important first steps.

3. *Compiling a list of natural enemies:* Literature records and entomological collections are a good starting point in building a list of potential control insect and plant pathogen candidates, followed by thorough field surveys and collections in the native ranges of the weeds. A survey of the already existing natural enemies in the U.S. problem area is also made at this time.

4. *Selecting the best control candidates:* The compiled list of candidates is divided into guilds, each candidate being grouped according to the plant part attacked, e.g., flower and seed feeding insects; stem and foliage defoliating insects, crown infesting insects, etc. The abundance and frequency of each candidate is assessed throughout its range as well as its potential to damage the weed plant. The presence of parasites that may be hindering the action of each candidate is noted. The size of the insect and the number of generations per year are two additional factors considered in assessing the control potential and host specificity of the candidates.

5. *Biology and host specificity studies:* The life cycle is studied, focus being placed on behavioral, morphological, and physiological traits that presumably tie the candidate to a particular plant structure, species, or group of plants. The actively feeding stages (adults and larvae in the case of beetles; larval stages in the case of moths, butterflies, and flies) are placed on selected test plants, some of which are closely related to the weed, plus others of varying and more distant relationships. Sufficient number of each stage (about 30) are tested on each test plant species (approximately 30 to 50 species of test plants) requiring from 200 to 1,500 pots and/or bouquets of the test plants. We try to do most of the testing in the foreign countries, but out of necessity, an increasing proportion of the work is done with U.S. native plants in U.S. quarantine facilities. In many instances the candidate insects have only one generation per year and must be matched to a particular growth stage of the test plant at the appropriate stage of its own development. In cases where we must test native plants, it may require 1 to 2 years to locate populations of the native species and another one to two seasons to establish the plants in quarantine in a condition suitable for testing. Again we need the assistance of botanists and plant experts in locating and obtaining propagules of our test plants.

6. *Excluding parasites and pathogens from the candidate organisms:* Prior to testing, we must ascertain whether the population is carrying a debilitating pathogen or parasite that might affect the test results, and, if possible, separate these organisms from the test population. In the case of insect parasitoids, this can be accomplished relatively easily, whereas in the case of entomophathogens, a 1- to 2-year study and effort may be required. In any event, the parasites and pathogens must be eliminated from the population before it is released into the new environment.

7. *Appraisal of host specificity test results:* A Federal Working Group on the Biological Control of Weeds (currently chaired by Dr. Rodney Bovey, USDA, College Station, TX, and including representatives from the USDA Forest Service, BLM, Fish and Wildlife, EPA, Army Corps of Engineers, National Arboretum, APHIS, and the USDA Agricultural Research Service) review the adequacy of the data and whether sufficient numbers of the appropriate plants have been tested. The results are also submitted to Canadian and Mexican officials for review. Each State quarantine officer must review the data before release in a State is permitted. The researcher may be requested to carry out additional studies.

8. *Release*: Release sites are selected, preferably ones climatically matched to the habitat from which the control candidate was collected. The site should be undisturbed or managed according to instructions for at least 5 years. The number of organisms released will vary with the characteristics and availability of each candidate. Numbers released at a site may range from 25 individuals to several hundred or even thousands. Ideally, a number of sites representing a spectrum of conditions are chosen.

9. *Evaluation:* Control depends on establishment, buildup, plus the timing and type of attack. The control process can be interrupted or slowed by unsuitable plant conditions, climate, indigenous predators or parasites (e.g., ants), and unforeseen disturbances. When well-established, excess natural enemies are collected and redistributed to new sites.

The greater the number and array of organisms attacking a plant, the more important will be their influence on its growth and reproduction. Plants native to an area often contend with a number of coevolving natural enemies and/or competing plantings that limit their potential to reproduce and spread. A dynamic balance between the plants and their environment is established. Management practices that upset this balance can lead to a detrimental increase of one plant species over another. In these instances, the introduction of additional natural enemies or the augmentation of already existing species may help restore the desired plant balance. To remain effective, the causal management practice that led to the problem must be corrected. Unfortunately, the uncertain outcome of introducing new natural enemies to control native weeds has raised questions whether the impact of the introduced organisms will be limited to specific populations of the weed or extend throughout the plant's range, perhaps even impacting on closely related native species. This uncertainty brings into question the appropriateness of introducing exotic insects to control native weeds. Biological control workers are looking for ways to respond to these concerns.

*Conclusion:* The biological control process has become increasingly complex. A number of steps are now required to clear exotic potential control organisms to the United States. Concern over the fact that these organisms may attack and impact on native plants has complicated the testing and decisionmaking process immensely. On the positive side, there has been increased recognition of the role that biological control might play in the control of weeds in the United States and the need for this approach.

The fact that most studies to date have focused on the collection, testing, and release of new natural enemies against introduced weeds, people often think of biological control as the substitution of "bugs" for chemicals to solve weed problems. More appropriately, biological control should be considered as the use and management of natural enemies to stress weeds and that the natural enemies are only one part of the weed/range management program. The release of exotic insects or pathogens is but a first step in the management process. To achieve a balanced range system, each manager should be aware of the capabilities and shortcomings of the control organisms and how to enhance their impact on the weeds. Each of us has to take an active part in the management process.

In terms of future prognosis, I see increased interest in biological control, as well as an increased awareness of the complexity of the range ecosystem. The economic importance of range weeds, in general, and key species in particular, will bring to a head, and hopefully a sound resolution, the conflicting questions of environmental quality as measured in terms of plant species diversity vs. the economics of range utilization for beef production. Awareness that the release of an insect (or chemical molecule) into the environment could impact on more than the target weed, the far-reaching consequences of which we cannot foresee at this time, should make managers, administrators, and society in general realize that some hard choices must be made. We must be aware of the motives behind our actions and that the economic balance sheet is only one factor to be considered. If there is uncertainty, we should go slow in the application of any technology until it is proven fully. We must take the responsibility for what we do—as well as what we do not do—and for what we create and what we say. Somewhere there exists the perfect solution and balance to every problem. Can we find this solution? Can we accept it?

## Progress in Biocontrol of Weeds of Southwestern Rangelands

**C.J. DeLoach,** *Agricultural Research Service, Temple, TX*

Control of weeds, including brush, is probably the most important problem affecting the grazing livestock industry in the southwestern United States. In Texas, 82 percent of all grasslands are infested with brush and nearly all of it with various herbaceous weeds and semi-shrubs. The density of brush has increased dramatically in the Southwest in the last 150 years, caused mostly by overgrazing, spread of seed by livestock, reduction in range fires, and periodic droughts. Ecologists now think that the original grasslands were a subclimax maintained by fire; the climax vegetation is desert shrub. Once this climax shrub vegetation is in place it will not go away unless forcefully removed. Although the causes are mostly related to improper management of the grasslands, several long-term experiments indicate that reduced grazing, even to total exclusion, does not reduce brush, or even halt its continued increase. Economics, mainly that many acres are required to produce one animal unit in this semiarid area, make control very expensive in relation to the return. Ranchers can barely afford present chemical and mechanical controls and the cost will probably increase considerably with the recent withdrawal of 2,4,5-T from the market, which was the most cost-effective treatment for brush.

Biological control by the release of foreign organisms, usually insects, is the most economical method of controlling weeds in rangelands. This is because the insects need be released in only a few sites from which they increase and spread on their own and actively seek out the target weed, giving permanent control; cost of control is thus largely independent of the area infested.

At Temple, TX, we have selected weeds amenable to biological control based on three criteria: (1) the weed (or its close relatives) occurs as a native species somewhere else in the world where we can find natural enemies; (2) the weed (or its close relatives) does not have overriding beneficial values, either directly to man or to the ecosystem; and (3) the weed causes sufficient losses to be worth the cost of the research.

This selection revealed that most of the major problem weeds of the Southwest that might be controlled biologically are native plants. Past research on biological control of weeds has all been with introduced weeds, except for three minor examples on islands, which are much simpler ecosystems than continents. However, there is a reasonable chance of success because most of the major weeds have close relatives (in the same plant genus) that are native in a similar climatic zone in northwestern Argentina and Paraguay. I and personnel of the ARS Laboratory at Hurlingham, Argentina, traveled 50,000 miles through this area over a 6-year period searching for natural enemies for control of rangeland weeds. A summary of the research on each target weed follows:

**Snakeweed** (*Gutierrezia sarthorae, G. microcephala*): Snakeweeds occupy 143 million acres in the United States. They seriously compete with desirable forage plants, and they are toxic to livestock; they cause an estimated $75 million in losses annually. The species in North America have essentially no beneficial values to man or to vertebrate animals; one species has been proposed as endangered, but it is of doubtful taxonomic validity. The genus *Gutierrezia* originated in southwestern North America where 16 species are native; 11 species also are native in Argentina and Chile. We found 36 species of insects and a plant pathogen in Argentina; about 8 or 9 of these species appear to have some promise for introduction. The Hurlingham Laboratory has intensely tested a root-boring weevil, *Heilipodus ventralis*, and we have begun testing it at Temple. It causes severe damage to snakeweed, but it also attacks equally *Grindelia* (gum-weed) and to a much lesser degree plants in four other very closely related plant genera. We are not yet sure if the weevil is safe enough to introduce. The Hurlingham Laboratory has begun testing a moth, *Carmenta haematica*, whose larvae also bore in the taproot; it appears to have a slightly more restricted host range. We also found three buprestid beetles, *Dactylozodes okea, D. alternans,* and *Agrilus leucostictus,* all of whose larvae bore in the taproot; a fly, *Strobelia baccharidis,* whose larvae make foam balls on the stems; a gelechiid moth that makes stem galls; a moth, *Aceptilia* sp., whose larvae feed on flowers; and scale insects, *Cerococcus* sp., that feed on the stem. All these insects are being considered for introduction.

**Baccharis** (*B. neglecta, B. glutinosa, B. halimifolia*): *Baccharis* shrubs are a pest especially in abandoned fields in central and southern Texas that have been converted to grazing. One species, *B. pilularis*, is used in California for ground cover and one species has been proposed as endangered. The genus originated in southern Brazil, where about 120 species exist. About 22 species are native in the United States. One species, *B. halimifolia*, has been introduced into Australia where it has become a major pest. The Australian Government has studied the natural enemies in Brazil and has released several species in the field in Australia. We have obtained one of them, the Brazilian stem-boring beetle, *Megacyllene mellyi*, from Australia, and we are now testing it in quarantine at Temple. We expect to receive another insect from Argentina in the near future, the leaf-feeding beetle, *Anacassis fuscata*. The conflicts of interest must be resolved before control agents can be released.

**Mesquite** (*Prosopis glandulosa* and *P. velutina*): Mesquite occupies 94 million acres in the United States and causes an estimated $100 million in losses annually through competing with forages and increased management costs. It has several beneficial uses, such as for shade trees, barbecue wood, small handcrafts, the pods for livestock feed, and experimentally as fuel for energy production.

The genus *Prosopis* originated in the Argentina-Paraguay area where 28 species are native; 9 species are native in the United States and Mexico. We have collected 258 species of insects in Argentina and Paraguay; 39 seem to have some potential for biocontrol, including insects that attack flowers, pods, seed, foliage, limbs, or trunks. We could, therefore, select the kind, and probably the amount, of damage produced by introducing the appropriate natural enemy. For example, insects that attack the reproductive parts would limit the spread without harming standing trees. Conflicts of interest must be resolved before control agents can be released.

**Creosotebush** (*Larrea tridentata*): The genus *Larrea* originated in Argentina where four species are native. Creosotebush was introduced into North America about 11,000 years ago. It rapidly invaded its new habitat in the southwestern deserts but invaded the grasslands mostly after livestock were introduced. It causes severe reductions in forage production but is not toxic. It has little beneficial value either to man or vertebrate animals. The Mexican Government initiated a program in the 1970's to use the sap to produce an adhesive and an anti-oxidant. This program apparently is proving to be not very economical.

We have found several insects in Argentina that bore into the stems and feed on the foliage. Some are promising candidates for introduction, but we have not yet begun host specificity and biological testing.

**Tarbush** (*Flourensia cernua*): Tarbush occupies similar areas as creosotebush, but is usually found on the deeper, better-watered soils. It is poisonous to livestock while flowering. I am unaware of any notable beneficial values either to man or in the ecosystem. The genus probably originated in North America; however, 13 species are native in Mexico (only 1, *F. cernua,* extends into the U.S.), and 16 are native in southern South America. We have found several stem-boring and foliage-feeding insects in Argentina that have some promise for biocontrol, but we have not yet started testing.

**Whitebrush** (*Aloysia gratissima*): Whitebrush is a severe problem in central and southern Texas and scattered areas further west. It forms impenetrable thickets but is not toxic. The genus *Aloysia* originated in Argentina and 11 species are native there and in Paraguay and southern Brazil; 9 species are native in Mexico, 3 of which extend into the United States. *A. gratissima* is also native in Argentina and may have been introduced into North America only a few hundred years ago. It is little attacked by insects or diseases here. It also is not heavily attacked by natural enemies in Argentina. We collected 82 species of insects and 4 plant pathogens there. Larvae of the moth, *Timocractica* sp., that tunnels under the bark, larvae of a beetle in the tribe Agrilini that bores in the stems, a rust pathogen, *Prospodium tumefaciens*, and a scale insect,

*Cerococcus* sp., have most potential for biocontrol. The only important conflict of interest in the U.S. is that whitebrush produces a premium honey and is much prized by beekeepers.

**Bitterweed** (*Hymenoxys odorata*) and **Pinque** (*H. richardsonii*): Bitterweed, an annual, and pinque, a perennial, are poisonous plants that cause serious losses to sheep from the Edwards Plateau of Texas, through New Mexico, and to Colorado, Utah, and Arizona. The genus apparently originated in southwestern North America where 24 species occur, but 4 species also occur from central Argentina to Peru. None of the species appear to have important economic or ecological values. So far, we have been able to find only a few natural enemies in Argentina. Larvae of a stem-boring fly and also stem-boring larvae of two other species of insects were found in Argentina, but they appeared to cause only slight damage. Thus, at this time, the conflicts of interest do not appear great, but the known control agents are not very promising either.

**Loco weed** (*Astragalus* spp.): Loco is a major poisonous plant of southwestern ranges, causing many deaths to cattle during cyclic outbreaks that occur each 3 to 6 years; it seldom is abundant enough to compete much with forage plants. The poisonous species have little or no beneficial values, but severe conflicts exist with other members of the genus that might also be attacked by introduced control agents. Over 400 species of *Astragalus* are native in North America; many have value in the ecosystem, some are used as forage plants, and some are rare or endangered.

About 90 species are native in southern South America, and we found several insects there that damage the seed pods and the roots. Since the North American pest species of *Astragalus* do not occur anywhere else, the insects from Argentina would be as likely to attack beneficial *Astragalus* as to attack the weedy species. We doubt that insects sufficiently host-specific could be found that would be safe to introduce.

**Salt cedar** (*Tamarix* spp.): Salt cedar is one of the few introduced weeds that is a serous enough pest of southwestern rangelands, and that is not already under study by another laboratory, to justify a research effort.

Four or five species have been introduced from the Middle East; some of these shrubs have become serious weeds in the floodplains of most Western streams, where they form dense thickets, replace native vegetation, and cause increased sedimentation and flooding. One species grows large and is considerably used in U.S. and Mexican arid regions as a shade tree. The plants are also of minor value for honey production and as nesting sites for the white-winged dove, which is a great favorite of dove hunters.

The prospects for successful biocontrol appear excellent if the conflicts of interest can be resolved. Many insects have been found in the Middle East and Pakistan that seriously damage plants in various ways. The kind and amount of control probably could be applied at will by introducing the correct insects. Since no other members of this plant family occur in the Western Hemisphere, there is very little chance that the introduced insects would attack nontarget plants.

The most serious problem in the biological control program of several of the most important weeds of southwestern rangelands is to resolve the conflicts of interest between those persons and groups who want the plants controlled and those who want to use them for something or who believe they have beneficial values in the ecosystem. A resolution of these conflicts must be obtained before foreign control agents can be released in the field. If the beneficial values outweigh the harmful values, then foreign organisms properly should not be released. The resolution will be made by evaluating the harmful, beneficial, and ecological values of each plant. Unfortunately, the information is woefully small on many of these aspects. Even for the amount of damage caused to the grazing livestock industry, good, solid data are pitifully lacking, and much of what is available is based on personal opinion, "best judgment" evaluations, "visual estimates," etc., which will hardly stand up under critical review.

Biological control appears to be technically feasible, economically sound, and not harmful (and may even be advantageous) to the ecosystem. Many of the weeds, including several native species, have increased so enormously in density during the last 150 years that they probably have had serious repercussions in the structure of plant communities and on the populations of many birds and mammals, in addition to being disastrous to the livestock industry.

With the extreme care exercised in safety testing, and the wide review of results that takes place before releases, it is practically inconceivable that a plant species would be eradicated by biological control. What we seek to accomplish is to reduce the abundance of a weed sufficiently to reduce the losses, and, incidentally, to return its abundance to a level more nearly like that before the beginning of the grazing livestock industry.

The biocontrol of certain native weeds also seems feasible, though it is more difficult and requires a more careful consideration of the effects on the ecosystem than does the control of introduced weeds. We believe that, with careful consideration of the various beneficial and ecological aspects of each weed, the biological control of certain species can be brought about.

## Biological Control of Noxious Weeds in Montana

**Norman E. Rees,** *Agricultural Research Service, Bozeman, MT*

Thirteen biocontrol agents have been released on 7 major problem weed species in Montana with varying results. In addition, a 14th agent has recently immigrated from a Canadian release site and is becoming established throughout much of the State.

*Chrysolina quadrigemina* was established on St. Johnswort in the Gallatin Valley in the early 1950's, but has not been successful in suppressing populations of this weed. A second beetle, *Agrilis hyperici,* has been released several times to assist *Chrysolina*, but has been unable to survive. Timing and lack of adequate amounts of moisture are thought to be the major reasons that these two agents were unsuccessful. Therefore, a small gall-producing fly, *Zeuxidiplosis giardi*, is now being studied and released at several sites in Montana.

*Rhinocyllus conicus*, a seed head infesting weevil of musk and several other species of thistles, is established in over 20 States and is reducing musk thistle populations in many areas. Nevertheless, a foliage feeding beetle, *Trichosirocalus horridus,* is being studied to see if it can survive Montana's winters. Additional insects are expected in the future.

*Ceutorhynchus litura*, a stem-boring weevil, is established on Canada thistle at several locations within the State, but is considered a marginal agent in that it needs other stress factors to amplify its effect on the plant. *R. conicus* also attacks Canada thistle, but is fairly ineffective since the agent affects the seed production and the plant reproduces mainly by vegetative regrowth. A seed head infesting fly, *Urophora cardui*, has been released at several locations within the State, but is only known to be established at one site. Those factors which differ at the successful site with other sites which favored establishment of the fly will be studied.

Several releases of the defoliating moth *Calophasia lunula* have been made on dalmation toadflax in Montana, but with disappointing results.

*Urophora affinis*, a seed head fly, has been released at many locations for control of both spotted and diffuse knapweed. A root beetle, *Sphenoptera jugoslavica*, was also released on diffuse knapweed, while a second seed head fly, *Urophora quadrifasciata*, has migrated south from Canada and covers much of Montana. Tests are to be conducted with *U. affinis* and a seed head moth, *Metzneria paucipunctella*, to determine if competition between the two insects results in less control than if only one is used.

The main problem with leafy spurge is that it is a complex of several very similar appearing species which are apparently quite different chemically. The leafy spurge hawk moth, *Hyles euphorbiae,* is extremely specific in that some representatives of this species can survive only on one species of spurge, while other members can only survive on another species. The root beetle, *Oberea erythrocephala*, was first released in the Gallatin in the summer of 1982, and at least the first generation will be bivotine. Releases of *Oberea* from cooler areas of Europe were made in south central Montana in 1983. Other species of insects are expected as they are cleared for release in the United States.

The weeds which we have discussed are generally in low enough numbers in their native lands that they are not considered to be a problem. This desirable status is the result of a living balance between each plant and the living organisms which rely on the plant for their survival, but which in turn, do not cause the plants extinction. It is this balance of nature that we hope to establish on the North American continent by the introduction of those bioagents which were left behind when the plant was introduced.

# Mine Reclamation

## Arid Lands

**Earl F. Aldon,** *Forest Service, Albuquerque, NM*

The two preceding panel members clearly gave fine presentations on the status of reclamation at this time. I wish to present some of our latest findings from research conducted in the Southwest and present what I think are future needs in reclamation research.

Some recent findings:

A. Increased surface mining of coal in the Four Corners area of the United States has caused concern as to whether cast overburden (spoil) contributes significant sediment due to runoff to the already high levels in area streams. Rainfall is low (avg. 15 cm/yr) on the Navajo Mine study area in northwestern New Mexico, but after 16 runoff events in 8 years, runoff plot data are well correlated and show runoff and sediment production from graded but otherwise untreated spoils are within tolerable limits. An average of two runoff events per year yielded 0.77 cm of runoff and 2,456 kg/ha/yr of sediment from an average storm of 2.24 cm of precipitation.

If the runoff plots were treated to reestablish vegetation at present, it would be possible to detect a 25-percent difference in runoff and a 50-percent difference in sediment after about the same number of runoff events that occurred during calibration. The Universal Soil Loss Equation was an inadequate predictor of sediment loss on these plots.

B. Mining reclamation specialists and government regulators need sound criteria for judging when reclamation is complete and expensive bonds can be released. We have done some research on determining some vegetation parameters for judging the quality of reclamation on coal mine spoils in the Southwest.

Three common and easily measured parameters are cover, density, and diversity. Data taken from studies on semiarid and sagebrush grasslands in the Southwest show the following values are reasonable estimates of these important factors:

| | Vegetation type 1—semiarid grasslands | | Vegetation type 2—sagebrush grasslands | |
|---|---|---|---|---|
| | Limits | Mean | Limits | Mean |
| Cover % | 8% to 37% | 18 | 11% to 37% | 22 |
| Density (plants $m^{-2}$) | 7 to 99 | 35 | 8 to 112 | 42 |
| Diversity | 0.57 to 1.92 | 1.20 | 0.51 to 2.24 | 1.45 |

C. Western wheatgrass (*Agropyron smithii*) will survive and spread when broadcast seeded on raw mine spoil receiving some additional moisture as a result of topographic shaping. In 8 years, this plant spread by rhizomes from an area 1.5 $m^2$ to 5.9 $m^2$ and 11.5 $m^2$ on the McKinley mine in western New Mexico.

D. Of special concern to reclamation specialists is how long plant stands will persist after reclamation is complete. Plantings on northwestern New Mexico raw mine spoils from 1973, examined for establishment (1975) and survival (1979), showed 75 percent survival of fourwing saltbush (*Atriplex canescens* (Pursh)Nutt.), each plant occupying 2.32$m^2$ (1.52 x 1.52 m). Alkali sacaton (*Sporobolus airoides* (torr.) Torr.) cover was 4 percent and had a density of 0.05 plant per $m^2$ (Aldon 1981).

E. A study by Cress (1982) found three native plant species—fourwing saltbush, galleta (*Hilaria jamesii*), and western wheatgrass—responded to varied watering regimens by producing greater amounts of proline as moisture stress increased. A comparison of the three species showed a trend toward greater survivability at lower soil moisture levels as the proline content increases. Cress used a frequency of watering of 3, 5, and 7 days and watering rates of 1.00, 0.75, 0.50, and 0.25 inches/application.

F. Recovery of soil biota on reclaimed areas is receiving much attention by researchers in the Southwest. Parter et al. (ms in press) have analyzed reclaimed coal mine spoils for above-ground primary production, detrital food web biota, and microorganisms involved in nitrogen transformation and nitrogen cycle components to determine the stability of these spoils during the first 4 years after reclamation. The bacterial based detrital food web was stimulated during the first year after reclamation, which decreased during successive years until it was similar to an unmined area in 4-year-old spoils. The fungal based detrital food web remained unstable throughout the first 4 years. The presence of nitrifiers, denitrifiers, $N^2$-fixers, and hetetrophic microflora and nitrogen uptake components indicated the potential for an active nitrogen cycle in reclaimed spoils.

In addition, Elkins et al. (ms in press) studied decomposition of barley straw and populations of soil biota on strip coal mine spoils in northwestern New Mexico. The spoils had been amended with straw mulch, wood chips and bark, topsoil and straw, or no organic additives. Decomposition rates were highest on the unmined area and the bark-wood chip amended spoils and lowest on the topsoil-straw amendment

and unamended spoil. There were no significant differences in populations of soil microflora among treatments. However, as indicated by decomposition rates, soil microflora activity was enhanced by organic amendments. Soil microfaunal populations were highest on the bark-wood chip amended spoils and unmined soil. Important soil mites, the oribatids, were found only in the bark-wood chip amended spoils and the unmined soils. These studies suggest that selected organic amendments to mine spoils may achieve reclamation goals faster than the more expensive topsoil/ mulch procedures currently used in reclamation procedures.

Fresquez and Lindemann (1982) in a greenhouse study showed topsoil inoculation taken from the San Juan mine area did not increase microbial parameters of a spoil taken from the same mine or of the rhizosphere of *A. canescens*. Spoils appeared to be unable to support an active and varied indigenous flora or the microorganisms introduced by the topsoil inoculant. Organic amendment of either sludge or alfalfa increased all microbial parameters. The increased numbers, dehydrogenase activity, and distribution of fungi were particularly evident in the rhizosphere. Providing an available carbon source was more critical in stimulating an active and varied spoil microflora than was supplying an inoculant source.

Some additional questions for research to answer are:

Will reseeded habitats have adequate reproduction, thus becoming self-perpetuating, stable ecosystems? What plant densities and species compositions constitute an adequate stand relative to the premine condition of the range? Will salt migration in saline and sodic spoils eventually degrade the quality of the surface material and reduce vegetative cover? How should reclaimed habitats be managed? This last question is of special importance. Current research is focused on the effects of intensity, frequency, and season of defoliation. These attributes all influence plant vigor and production. Understanding the plant responses to defoliation will allow for developing guidelines for proper grazing management programs.

Future research will involve livestock grazing to establish stocking rates, utilization patterns, plant response to actual grazing, and dietary botanical composition.

**Acknowledgment**

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# Workgroup Reports

## Information and Publications

**Dan W. McKenzie,** *Chairman*

**Activities**

- The VREW 37th annual report on the February 13 and 14, 1983, Albuquerque, NM, meeting was prepared, and 3,000 copies were printed and distributed.

- The agenda for the 38th annual meeting, Rapid City, SD, February 14 and 15, 1984, was prepared and distributed.

- Two reports were published and distributed by San Dimas Equipment Development Center (SDEDC):
  *Range Fencing Systems State-of-the-Art Review*
  *Preventing Livestock Water from Freezing*

- The Chemical Plant Control Workgroup is working on an aerial herbicide application handbook. See Chemical Plant Control Workgroup report by Ray Dalen for more information.

- Farnum Burbank, Forest Service Engineering Staff, Washington Office, prepared an article for the Forest Service publication *Engineering Field Notes* about the VREW. This article has been reprinted on page 2.

- Marianna Pratt, managing editor, *Agricultural Engineering Magazine,* featured a cover story article on the land imprinter titled, "Land Imprinting for Lasting Impressions," in the September 1983 issue.

**Projects**

With the completion of the range habitat improvement video tape project (OE02D19), only one VREW-funded project comes under the Information and Publications Workgroup, Problem Area Investigation and Definition (1E11D42).

The goal of this project is to prepare a separate prospectus if further development is indicated, or prepare a report if development work is not desired on each problem area suggested. A number of range equipment problem areas have been suggested and prioritized. Four prospectuses and one report have been completed and one report is in final preparation. Suggested range equipment problem areas, in order of priority and current status, are:

1. Arid Land Seeder: *Arid Land Seeder Development—A Prospectus* has been completed. The prospectus was prepared by SDEDC and Jornada Experimental Range, ARS, Las Cruces, NM. An article was prepared for the December 1983 issue of *Rangelands*: "Arid Land Seeder Development." In a review of projects by VREW's Exploratory Committee at Long Beach, MS, July 18, 1983, a consensus was reached that while the arid land seeder was biologically acceptable and technologically possible, it was not economically acceptable (the cost per acre of operating the arid land seeder is too high and would not be a good investment). Therefore, VREW will make no further expenditures for development of the arid land seeder at this time.

2. Range Fencing Systems: A report, *Rangeland Fencing Systems State-of-the-Art Review,* has been completed. The report was prepared by Colorado State University, Fort Collins, CO, and SDEDC. Conclusions from the review were:

- Conventional rangeland fencing systems and practices have reached a state of development where new and innovative fencing systems are not expected to emerge that will result in a substantial cost reduction of range fencing.

- Two types of fencing do offer some possibility of reducing fencing costs when used under proper circumstances. They are the New Zealand electric fencing systems and high-tensile, smooth-wire fencing systems.

- Reduction in fencing costs could also be achieved by using the diagonal brace in place of the horizontal brace for corner, gate, or fence and braces.

- Many good local practices offering cost reductions are in use or are being developed that are not well documented.

- Fencing considerations for wildlife or other special functions exist in literature, but not in one useful reference source.

In addition, an investigation into fence brace (strainer) failure and designs may yield cost reductions. Corner, line, and gate or fence end strainers are an important part of any fence. With the increased use of high-tensile, smooth-wire, good strainer design is of even greater importance because of the higher loading and necessity of maintaining the complete fence at the recommended tension.

The Colorado State University Agricultural Experiment Station, Fort Collins, CO, expanded on the material collected in this review, and published a report titled *Electric Fencing for Rangelands,* Special Series 27. This report can be ordered for $3.25, post paid, from Bulletin Room, Colorado State University, Fort Collins, CO 80523, (303) 491-6198.

3. Disk-Chain Implement: *Development of a Disk-Chain Implement for Seedbed Preparation on Rangeland—A Prospectus* has been completed. The prospectus was prepared by the Texas A&M University, Agricultural Research and Extension Center, and SDEDC. The Texas Agricultural Experiment Station demonstration model disk-chain has validated, by the treatment of almost 2,000 acres, the improved grass-stand establishment effectiveness over smooth chaining with a predicted cost reduction of seedbed preparation of ½ to ¾ when compared to seedbed preparation by use of standard disking equipment. To complete the development of the disk-chain, a full-scale engineering development effort must be undertaken and completed. The Missoula Equipment Development Center is working with the Texas Agricultural Experiment Station to design, fabricate, and evaluate a production prototype disk-chain.

4. Punch Seeder: *Punch Seeder for Arid and Semiarid Rangelands—A Prospectus* has been completed. The punch seeder prospectus was prepared by the University of Idaho, Moscow, Idaho, and SDEDC. The concept of punch seeding has been shown by research experiments to have merit. This seeding technique now needs to be demonstrated and validated in the field. A self-propelled, rubber-tired, intermittent, dibble-type container transplanter, now under development by the Agricultural Engineering Department at the University of Idaho, could be used to demonstrate and validate punch seeding. If, after evaluation of seedings, the results indicate the desirability of punch seeding, full-scale engineering development of a punch seeder can begin by the design and fabrication of a production prototype.

The Exploratory Committee recommended at its July 1983 meeting further development of the punch seeder. The Missoula Equipment Development Center is working on plans, in cooperation with the University of Idaho, to operate the self-propelled, punch seeder/dibble-type container transplanter on the Caribou National Forest near Pocatello, ID.

5. Mulch-Spreading Equipment: A state-of-the-art review on mulch-spreading equipment for steep-slope revegetation and mine reclamation is being prepared. The investigation showed development of new mulching equipment for mineland reclamation and steep-slope revegetation to be unnecessary by Government agencies. The requirements for mulch-spreading equipment recommended by industry experts and researchers are largely met by available equipment, and manufacturers are actively improving existing designs to fully meet requirements. The report on mulch-spreading equipment is being prepared by Colorado State University, Fort Collins, CO, and SDEDC.

6. Backhoe Containerized Shrub Injection Planter Attachment: *Development of a Containerized Shrub Injection Planter Attachment for a Backhoe—A Prospectus* was completed. The prospectus was prepared by the University of Idaho, Moscow, Idaho, and SDEDC. The Forest Service Intermountain Forest and Range Experiment Station at Boise, Idaho, estimates that by using a 35-foot-long boom, between 65 and 75 percent of the cuts and fills in the Idaho Batholith could be planted mechanically. The concept was shown to have merit through simulation studies. What is needed now is to demonstrate and validate this planting procedure in the field with a demonstration planting device. In the review of VREW projects in July 1983, the Exploratory Committee recommended no further expenditures at this time because of insufficient demand.

7. Backpack Seed Collector: The Missoula Equipment Development Center has initiated investigative work on the backpack seed collector.

Work has not yet started on the following:

8. Reclamation of mine spoil by vertical mulching.

9. Investigation of self-leveling tractors.

10. Mineland trencher.

11. Mulch-gathering equipment.

12. Bandoleer grass transplanter.

13. Investigation into fence strainer failures and design.

14. Equipment for control of noxious weeds.

15. Rangeland furrowing equipment.

**Plans**

1. Prepare, publish, and distribute VREW 38th annual report.

2. Prepare and distribute 45 days in advance of meeting agenda for 39th annual meeting, which will be in Salt Lake City February 10 and 11, 1985.

3. Complete the report: *Mulch Spreading Equipment for Steep Slope Revegetation and Mine Reclamation—A State-of-the-Art Review.*

4. In cooperation with Texas A&M University, Agricultural Research and Extension Center, complete development of the disk-chain implement.

5. In cooperation with the University of Idaho, demonstrate and validate punch seeding.

6. Report on the investigative effort on the backpack seed collector.

**International Conference on Arid Lands**
An International Arid Lands Research and Development Conference will take place at the University of Arizona, Tucson, AZ, October 20-26, 1985. This week-long meeting is sponsored by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) and the University of Arizona Office of Arid Lands Studies, College of Agriculture. The conference will mark UNESCO's 25th anniversary and will be held during the University of Arizona's centennial celebration year.

The program will include invited papers and volunteer papers on four themes:

- Water use, conservation, allocation.

- Agricultural systems and the adaptations of their plant and animal resources.

- Natural resources reclamation, conservation, use.

- Human habitat—architectural, urban planning, cultural adaptations.

Cochairman for the conference are Dr. Jack Johnson, associate dean, College of Agriculture, and Dr. H.E. Carter, research fellow, Office of Arid Lands Studies.

For more information and advance registration details, write Dr. G.P. Nabhan, Office of Arid Lands Studies, University of Arizona, Tucson, AZ 35721.

## Seeding and Planting

William J. McGinnies, *Chairman*

### Seedbed Preparation—The Forgotten Step in Range Seeding

Range revegetation normally consists of four steps:

- Elimination of competition.
- Preparation of the seedbed.
- Planting.
- Protection.

Of these, the one most frequently overlooked or ignored is seedbed preparation. Seedbed preparation, as the name implies, involves the cultural treatments used to produce a suitable medium for germination, establishment, and growth of the seeded species. One might assume that because many of the species used in range seeding, at least as mature plants, grow on harsh sites, their seedlings should be able to readily become established under unfavorable conditions. Usually such is not the case. Many of the species used in range revegetation are difficult to germinate and have low seedling vigor, so it is important to provide nearly ideal environments for their germination and seedling growth.

The development of sturdy range seeding equipment that can be operated on rough seedbeds with minimum machinery breakage does not eliminate the need for carefully prepared seedbeds. I believe that poor seedbed preparation is a major cause of poor stands and failure in range seeding. Most poorly prepared seedbeds are excessively rough and loose. Such a seedbed contributes to failure because seeding depth cannot be accurately controlled and because soil moisture relationships are unfavorable for the seed and seedlings. Where plowing has been used to eliminate competition, the seedbed commonly receives no additional cultivation and no firming. On strip mines, the topsoil is frequently moved when too wet, and large, hard clods are left for a seedbed. In any case, one rarely sees a carefully prepared, smooth, firm seedbed on a range seeding project.

Seed of most species used for range seeding is small, and seedling vigor is low. Planting seed of most of these species below 1 inch (fig. 1c) results in seedlings failing to reach the soil surface, and there is a great reduction in seedling emergence. Because of surface soil drying, much of the seed planted less than ½ inch deep (fig. 1a) will fail to germinate. Thus, careful control of seed depth is essential to range seeding success (fig. 1b).

Consider the case of crested wheatgrass. In a study in Colorado, increasing seeding depth from 1 inch to 1½ inches reduced seedling emergence and establishment by 45 percent; when seeding depth was 2 inches, establishment was reduced by 72 percent. Although small grains are frequently planted several inches deep, one must remember that a wheat seed is 25 times heavier than a crested wheatgrass seed, and the greater energy reserve in the wheat seed permits the wheat seedling to emerge from the greater depth.

To obtain accurate seed placement, the seedbed must be firm and smooth so that depth-bands will be able to control the penetration of the drill disks (fig. 2). If the seedbed is loose, the drill-disks will penetrate too deeply, and if the seedbed is excessively compacted, the drill-disks will not penetrate to the desired depth. To a lesser extent, single-disk drills equipped with depth-bands can provide reasonably good control of seeding depth, but only on a smooth, firm seedbed. For seed that is to be planted ½ to 1 inch deep, ¾-inch depth-bands can be used so that the seed will be placed within that range. Some species may need to be planted shallower or deeper, and with appropriate depth-bands, these depths can be achieved if the seedbed is suitable.

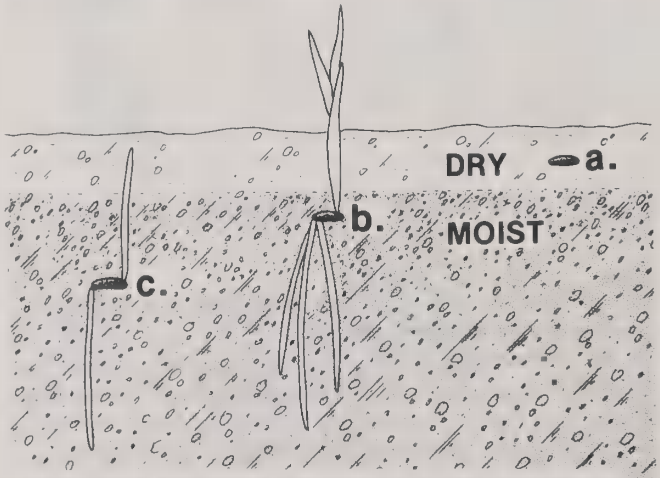


Figure 1.—Soil surrounding shallowly planted seed (a) dries out quickly, but if seed is planted too deeply (c), the seedling is unable to emerge. Optimum planting depth (b) places seed in soil that remains moist and yet is near enough to the surface to permit seedling emergence.

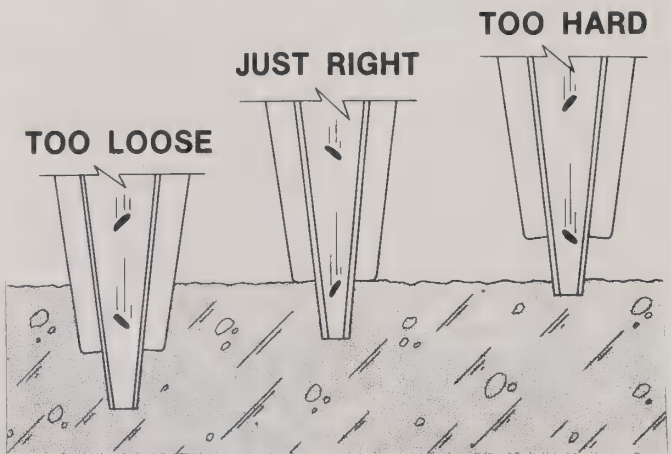


Figure 2.—Planting seed with a double-disk drill equipped with depth bands. If seedbed is too hard, the disks will not penetrate to the proper depth (right), and if the seedbed is too loose (left), seed will be planted at an excessive depth. Depth bands control planting depth on a firm seedbed (center).

Seedbed firmness also has a great effect on soil moisture relations. Soil firmness affects capillary pore space, and the amount of moisture that a seedbed can hold is directly related to the amount of capillary pore space (fig. 3, left). If the seedbed is loose, there will be a large amount of pore space, but the pores will be too large to serve as capillaries for soil water, and the water will drain out of the system (fig. 3, right). If the soil is excessively compacted, total pore space, including capillary pore space, will be reduced.

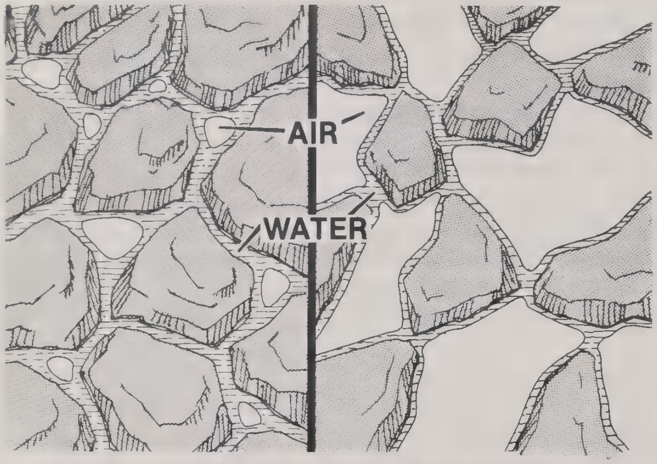


Figure 3.—Soil correctly firmed (left) will contain capillary pore space, which is capable of holding a maximum amount of soil water, but a loose soil (right) contains a few capillaries and will retain little water.

The ideal seedbed will be sufficiently firmed so that there is adequate capillary pore space, and yet is not so compacted that the reduced pore space prevents water infiltration. The well-firmed seedbed has many interconnected capillaries, and capillary soil water movement will occur between wet and dry areas in the same manner that water rises in a capillary tube (fig. 4). Soil that dries during the day will be partially rewet during the night and water taken up by seeds and roots will be replaced by capillary water movement (fig. 5, left). In loose soils, with very few interconnected capillary pores, water can move only in the vapor phase, and vapor movement is very slow (fig. 5, right).

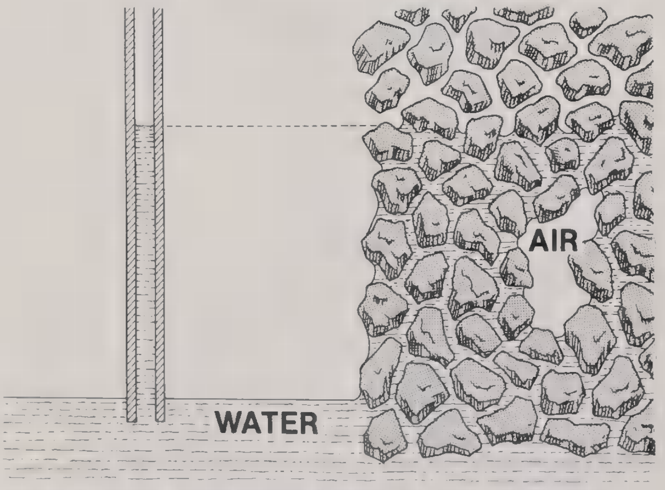


Figure 4.—Water moves through soil capillary spaces in the same manner that water will rise in a capillary tube (after Lyon and Buckman).

Rate of drying of the soil surrounding the seed frequently can be reduced by deep-furrow planting (fig. 6). A well-firmed seedbed is needed to reduce soil sloughing that can result in the seed becoming buried too deeply with soil in the furrow bottoms.

The methods used to prepare a seedbed depend upon the previous treatments. If the area was plowed when soil moisture was optimum, harrowing and cultipacking should be enough to produce a smooth, firm seedbed. Replaced topsoil on strip mines is usually severely compacted by the heavy scrapers used to spread the topsoil, and some tillage practice, such as ripping or chisel-plowing, is necessary to eliminate the compacting before the soil can be harrowed and cultipacked. Where topsoil has been handled when too wet, hard clods are produced. The best treatment for these (if time permits) is to fallow the area over a winter and hope that the freezing and thawing will break down the clods. In some cases, the vertical-axis rotary tiller may be of help. Because of the difficulty of working up a good seedbed from these hard clods, every effort should be made to avoid handling topsoil when it is too wet.

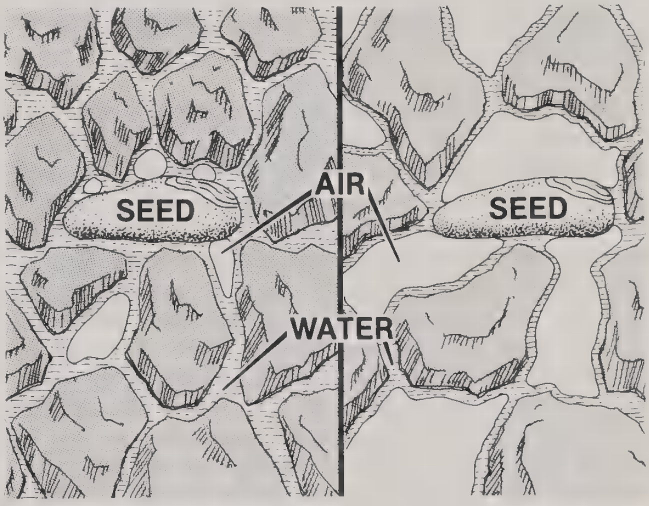


Figure 5.—Seed planted in a firmed soil (left) will be in contact with a maximum of soil water while seed planted in a loose soil will have less contact with soil water.

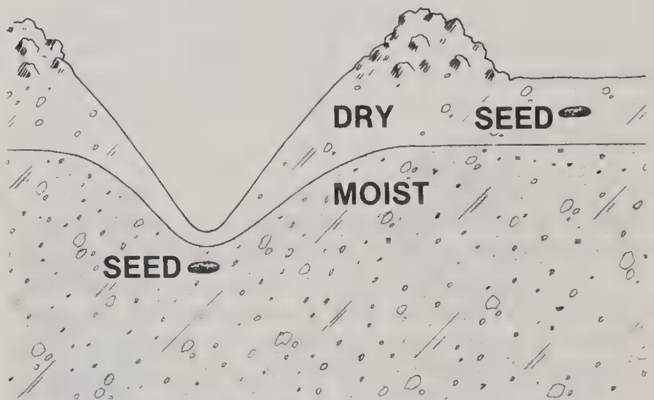


Figure 6.—Seed planted with a deep-furrow drill (left) is placed in soil that remains moist longer than conventionally drilled seed (right).

On sites where trees or shrubs contribute a large quantity of woody trash, some means of shredding and incorporating the trash must be employed or else the trash must be disposed of by burning or raking before plowing. Most farm machinery will not handle woody trash satisfactorily.

Little attention has been given to developing tillage equipment designed specifically for seedbed preparation on rangeland (except for plows), and because so little attention has been given seedbed preparation, the need for development of such equipment has not been fully evaluated.

The tillage operations used to produce a smooth, firm seedbed are an additional expense to be added to the already high cost of range revegetation. In many cases, however, the better seedbed will permit lower seeding rates which in turn will reduce seeding costs. It is also anticipated that the failure rate will be lower and costs of replanting reduced.

Better seedbed preparation will also reduce the need to develop and purchase specialized range seeding equipment because a smooth, firm seedbed can be readily planted with commercially available farm and pasture drills, and this can be a considerable saving.

Triangular disk-chain developed to prepare seedbeds on extensive areas of log-littered rangeland.

## Arid Land Seeding

### Harold T. Wiedemann, *Chairman*

A symposium on Range and Pasture Seeding in the Southern Great Plains was conducted in Vernon, TX, by committee members Chet Dewald, Richard Heizer, and myself.

The symposium featured the most recent plant material releases, and the latest seeding methods, seed planting and harvesting equipment and seed modification/processing techniques. Art Armbrust, Sharp Brothers Seed Co., Healey, KS, was the keynote speaker. More than 300 people from 5 States attended the meeting. Many of the attending seed producers believed that the equipment and techniques displayed and discussed would greatly influence the grass seed industry over the next decade. A limited supply of the proceedings is available at $5 per copy (contact Harold T. Wiedemann, Texas Agricultural Experiment Station, P.O. Box 1658, Vernon, TX 76384).

As a result of the prospectuses published by the Arid Land Seeding Workgroup on expanded VREW activities and goals, two of the equipment development articles, the arid land seeder and disk-chain implement, are being published in *Rangelands*.

Further activities are included under individual reports.

### Triangular Disk-Chain Activities

By Harold T. Weidemann, *Texas Agricultural Experiment Station, Vernon, TX*

The triangular disk-chain developed by the Texas Agricultural Experiment Station for low-cost seedbed preparation on log-littered rangeland has functioned well in field tests during 1983.

In kleingrass establishment studies, there was no significant difference in plant densities between seedbeds prepared by the triangular and diagonally pulled chains (0.79 vs. 0.76 plants/ft$^2$). Plant densities were increased by smooth chaining following both disk-chaining techniques (0.86 chaining vs. 0.69 no chaining $P=0.06$) prior to aerial seeding.

In draft requirement studies using 24- and 28-inch-diameter disk blades, the triangular disk-chain reduced draft by 36 percent and increased operating width by 23 percent compared to the diagonally pulled chain. Differences were significant at the $P<0.001$ level. The optimum size, 24-inch disk blade and 2-inch chain, required 150 pounds per blade draft in freshly disturbed soil. These and other data are covered in ASAE Paper No. 83-1609 available from the author.

## Woodward Laboratory Air-Seed Shucker for Rapid Quality Determinations of Chaffy Seeds

By C.L. Dewald, *Agricultural Research Service, Woodward, OK;* A. Beisel, *Aaron's Engineering, Fargo, OK*

The Woodward laboratory air-seed shucker (fig. 1) gives rapid extraction of caryopses (grain) from chaffy seed for a quick and accurate determination of pure seed content. The air-seed shucker is powered with compressed air which enters the power unit nozzel and travels through the mixing chamber to exit through a venturi muzzle at supersonic speeds. Air-entrained chaffy seeds enter the mixing chamber and are subjected to an impelling air blast and acceleration force that strips subtending appendages from the grain. When the grain is shucked, its density (mass/volume) is increased and it drops from the shucker against a vacuum resistance in the classification cylinder. Seed not shucked on the first pass through the power unit exit the venturi muzzle, travel with the air through a recycling tube and re-enter the system by means of a cyclone air separator until shucking is completed.

Determination of pure seed content of chaffy seeds by standard methods is slow, tedious and subject to much human error due to a large volume per weight ratio and extraneous materials to contend with. Two to four hours are required for a single purity analysis by standard methods, whereas comparable determinations can be done in less than 2 minutes with the aid of the air-shucker. More accurate as well as more meaningful results are obtained when the extracted grain method is used. In addition to the seed analysts, seed producers and processors will benefit by the rapid extraction method in timing of operations and monitoring pure seed content with the Woodward laboratory air-seed shucker.

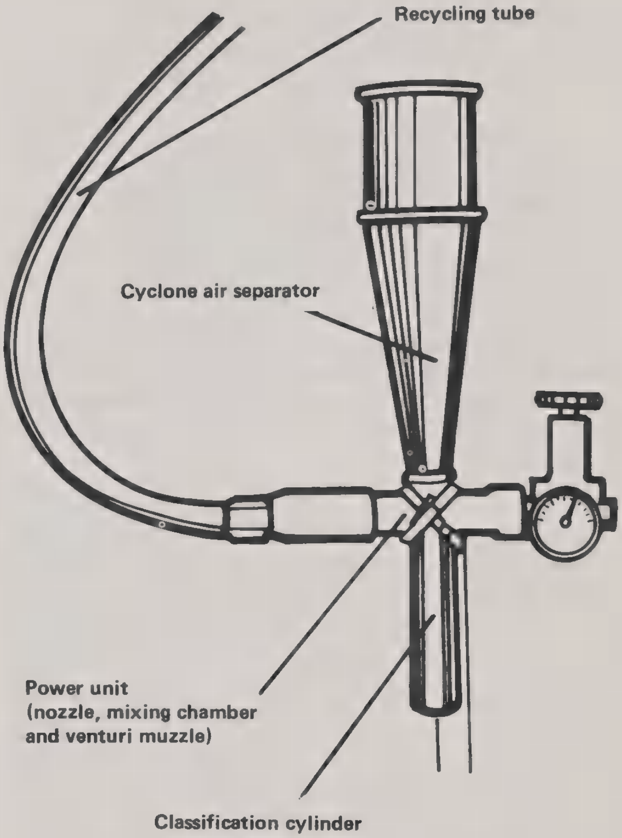


Figure 1.—The Woodward Laboratory Air Seed Shucker.

## Disturbed Land Reclamation

**James L. Smith and Willis Vogel**, *Co-Chairmen*

### "Native" vs. "Exotic"—The Dilemma of Ecologically Sound Mine Waste Revegetation

By Stuart A. Bengson, ASARCO, Inc., Sahuarita, AZ

**Abstract**
The restrictive regulations requiring exclusive use of "native" species for revegetation of mining wastes and disturbances is creating a perplexing and unnecessary dilemma. For the most part this problem was created by law and rule makers who knew little, and understood even less, of ecological systems. In theory the prerequisite of using "natives" is ideal, and to the purist is the only *acceptable* method of reclamation. In reality, the restrictive use of "natives" only creates a technological, practical, and ecological nightmare.

Once an ecosystem is altered, as in mining, it is no longer "natural"; it, in itself, becomes "exotic" (man-made). Therefore, to require the reclamationist to recreate a "native" ecosystem restricts any innovation, ecological balance, and improvement of the basic land resource.

A "native" ecosystem is *not* always the most productive, nor the best suited, in terms of reclamation and future land uses. Lastly, while the "native" species requirement may be the most expedient to install (no matter how costly), it may fail ecologically. This is neither good stewardship of the land nor should it be encouraged. The use of some "exotics" (where ecologically sound) should be encouraged to reestablish productive "naturalistic" ecosystems that will enhance the surrounding undisturbed "native" ecosystems.

ASARCO has had over 15 years, experience in creating viable "naturalistic" ecosystems in the arid Southwest utilizing both "native" and "exotic" plant species. This experience has proven that species selection must be based on the specific site requirements and *not* limited to the few "native" species that may be endemic to the site. The mixture of "native" and "exotic" species creates a productive ecosystem that enhances the land resource values and harmonizes with the adjacent undisturbed "natural" areas. Today, ASARCO is extending its experience in species selection to economic commercial species.

## Thermal Plant Control

**Bill Davis**, *Chairman*

### Merritt Island Brush Burning

By Dick Hallman, Forest Service, Missoula, MT

The Merritt Island National Wildlife Refuge, near Titusville, FL, is unique in several ways. The refuge, as part of the Cape Canaveral and Kennedy Space Center complex, occupies the area jointly with missile launch sites, a shuttle craft landing site and other NASA facilities. In addition to managing the diverse wildlife on the island, the Fish and Wildlife Service is also responsible for wildfire management on the area.

Refuge personnel are faced with the more or less usual problem of controlling fires on thousands of acres of land that is intermingled with marshes, rivers, and lakes. Personnel prescribe burn about every 3 years using the helitorch and a monsoon bucket to keep the fuels loading down.

Refuge managers face another fire management problem that is unusual. Within the refuge are approximately 260 miles of dikes. The dikes were built to create and regulate large mosquito control lagoons. As with the other lands within the refuge, fuels buildup on the dikes is rapid. The dikes must be kept open for administration and management. After about 3 years even four-wheel-drive vehicles cannot operate on the dikes. Chemical control is a questionable option because of the plant and animal life in and around the lagoons. Mechanical control is too expensive. Fire, therefore, seemed the logical option.

The Fish and Wildlife Service was aware of the Forest Service's Equipment Development Program through its contacts with VREW. They arranged the transfer of a truck-mounted boom-burner from the Missoula Equipment Development Center for evaluation. The 25-foot burner was equipped to burn diesel fuel.

The burner was evaluated by refuge personnel during December 1983. They found that the boom can easily cover the fuels on both sides of the dike and that they could ignite fuels on one side of a dike while driving over 4 miles per hour. The Fish and Wildlife Service will continue to evaluate this ignition equipment in an attempt to perfect a rapid system for managing the vegetation on the many miles of dikes on the Merritt Island Refuge.

Truck-mounted boom-burner from the Missoula Equipment Development Center.

# Mechanical Plant Control

**Gus Juarez**, *Chairman*

## Mechanical Control of Sagebrush

By William F. Davis, Forest Service, Ogden, UT

**Abstract**
The success of sagebrush (*Artemisia* spp.) control must be measured according to the objective to be obtained. Where seeding other species for forage and longevity is an objective, then a high degree of initial control of existing sagebrush plants is necessary.

**Introduction**
Before selecting a method or combination of methods to be used for mechanical control of woody species of sagebrush (*Artemisia* spp.), one should first identify the habitat types or sagebrush subspecies to be treated. This information provides insight into the site potential for herbage production (McDonough and Harniss 1975). It also aids in selecting species for seeding and defining realistic objectives to be accomplished by the control effort (Hironaka and others 1983).

Methodology is too often selected because of initial cost or equipment availability. Ideally, one should identify the results desired based on well-developed objectives and then select the most appropriate methodology. Economics is an important factor to be considered in selecting a method for sagebrush control. Frequently, only the investment cost of the initial treatment is considered. Inadequate attention is often given to the quality of seedbed preparation, the timing of seeding, the degree of control of competitive species, the short- and long-term benefits to be obtained and necessary followup treatments (Frischknecht and Bleak 1957; Nielsen and Hinckley 1975).

Many variables influence the success of initial sagebrush control and the reinvasion of shrubs into the treated area. The greatest economic return for livestock results from methods that require the shortest periods of nonuse and yield at least 15 years of relatively uniform production (Pechanec and others 1954).

Some sagebrush eventually reinvades most treated sites. The rate of return is primarily related to the effectiveness of the initial control (Welden and others 1958) and the success of the seeding (Robertson and others 1966). Shrub reestablishment has been reported to occur in wet years (Frischknecht and Harris 1968) and is hastened by heavy grazing (Johnson 1969). However, Bartolome and Heady (1978) found no significant correlation between shrub reestablishment and amounts of moisture received on grazed ranges, but reported that sagebrush invades rapidly after treatment and may continue to increase for several years thereafter. Frischknecht and Harris (1968) reported that in some years reinvasion occurred even without grazing.

Hull and Klump (1966) described treatments consisting of sagebrush removal followed by crested wheatgrass (*Agropyron desertorum* or *Agropyron cristatum*) seedings at nine locations in southern Idaho. These seedings were all below 5,800 ft (1,768 m) elevation on abandoned farmland, plowed or fallowed land, or recently burned areas. The authors assumed that little sagebrush escaped removal from the sites prior to seeding. They found that many of the 30-year-old seedings were still productive and most showed no sign of deterioration after more than 20 years of rotation grazing at about 3 acres (1.2 ha) per animal unit month. However, they also recommended a maintenance sagebrush control at some locations every 10 to 20 years. Such recent observations at these and similar sites indicate that plantings on the most productive sites tend to be reoccupied by sagebrush sooner than plantings on drier sites, and that mountain big sagebrush and basin big sagebrush are more aggressive than Wyoming big sagebrush (U.S. Department of Agriculture, Forest Service[1]).

Blaisdell (1949) pointed out that sagebrush plants that survive brush control treatment have a distinct advantage over seedlings of planted grasses. However, sagebrush seedlings that became established at the same time as the grasses did not always display an initial advantage. Plummer and others (1955) stressed elimination of competing species by comparing sections of a 2-year-old crested wheatgrass seeding. The seeded grasses produced 1,785 lb (809 kg) of air-dry grass per acre in areas where 92 percent sagebrush control occurred, and 529 lb (240 kg) of air-dry grass in areas with 53 percent sagebrush control.

Bartolome and Heady (1978) conclude that the reinvasion of sagebrush on treated sites in Oregon was due to the recovery of plants that had not been killed and the growth of seedlings established during the first few years following treatment. Shrubs that established in later years usually remained small and did not mature. Sagebrush reinvasion did not result in deterioration of the perennial grass stand or in a reduction in grass production.

Efforts to control sagebrush have had a long interesting history. Burning and mechanical techniques were essentially the only methods available until herbicides came into use following World War II. Increased interest in seeding or otherwise improving depleted ranges following the war led to the 1946 organization of the Range Seeding Equipment Committee, now the Vegetative Rehabilitation and Equipment Workshop (VREW), which has devoted a great deal of time and effort to the testing and development of suitable equipment for range improvement (Larson 1982).

[1] USDA Forest Service, Intermountain Region, 1960-1983.

## Mechanical Equipment for Sagebrush Control

### *Root Plows*

Several early attempts were made to design and construct root plows to treat woody species. These plows worked reasonably well on moderate to deep soils that were free of rocks, but power requirements were high compared to plow width and digging depths. Large root plows provided acceptable kill of root sprouting shrubs in the Southwest (Gonzalez and Dodd 1979). Although they have been successful for controlling sagebrush in the Intermountain area, they also destroy desirable herds and shrubs. The blades are drawn laterally through the soil, cutting and uprooting all species. Soil moisture levels, percent of rock, and density of vegetation determine the power requirements and production rates. Under normal conditions, 1 to 4 acres (0.4 to 1.6 ha) can be treated per hour (Larson 1980).

### *Brush Rake*

Various types of rakes have been tried but none have proven successful for elimination of sagebrush. Older woody brush can be removed, but younger, more flexible plants remain. Most rakes were not built to treat low growing shrubs, consequently their use of rangelands is quite limited (U.S. Department of Agriculture, U.S. Department of the Interior, Range Seeding Equipment Committee 1957).

### *Dixie or Pipe Harrow*

The pipe harrow got its beginning on the Dixie National Forest in Utah. Spikes were driven into green poles that were attached parallel to each other and pulled length wise by a team of horses. Some success was obtained, and soon the steel harrow appeared (Plummer and others 1955). Self-cleaning pipe harrows are well adapted to rocky and rough ground. They are most effective for covering broadcast seed or burns in areas where trees or rocks prevent the use of larger equipment. They are only moderately effective in controlling brittle sagebrush plants. Twice-over treatment of brittle brush has been reported to control 70 percent of the brush, although this is believed to be the exception rather than the rule (U.S. Department of Agriculture, U.S. Department of the Interior, Range Seeding Equipment Committee 1957). Depending on the terrain and shrub density, up to 3.4 acres (1.4 ha) per hour can be treated using a 14-ft-wide (4.3-m) harrow drawn by a 50-hp (67.0-kW) (drawbar) tractor (U.S. Department of Agriculture, U.S. Department of the Interior, Range Seeding Equipment Committee 1965).

### *Rail Drags*

Rail drags appeared in many configurations and were probably the first successful implements used to control shrubs. Designs of importance are essentially either single bars or a series of bars pulled in tandem. The bottom of the rail is the cutting edge and slides along next to the soil. To provide a cleaning effect, most drags are either built in sections or in an open V or A configuration (U.S. Department of Agriculture, U.S. Department of the Interior, Range Seed Committee 1957).

Satisfactory kill of sagebrush is seldom obtained unless the shrubs are over 2 ft (0.6 m) tall and old enough to be brittle. Because young plants usually are not affected by the treatment, only 30 to 80 percent of most stands are killed. Large rocks and cold weather contribute to substantial equipment damage (Pechanec and others 1954). Power requirements are relatively high, 40 to 60 hp (31 to 45 kW) for a 16.5-ft (5.0-m) A-rail unit width. The "supp rail" and the "rail drag" designs require less power (Larson 1980).

Lightweight rails were often used to mash tall brush down, forming a continuous fuel supply prior to prescribed burning and seeding. Sagebrush kills of up to 99 percent have been attained using this combination of techniques (U.S. Department of Agriculture, Forest Service, see footnote 1).

### *Brush Beating*

Brush beaters employ a series of hammers or flails attached to a horizontal shaft that is rotated at high speed using the power take-off from a tractor. Some units are powered hydraulically or by separate engines. Once-over beating seldom provides good kill of large sagebrush; twice-over beating is usually required to reduce the large stems to litter. Large rocks and woody stems over 3 inches (7.6 cm) in diameter damage the beater (Plummer and others 1955). Short or flexible brush normally cannot be controlled by beating.

Brush beaters have not proven adequate for control of brush on Forest Service projects. Power requirements are high in relation to acreage covered, although 20-hp (14.9-kW) tractors have successfully powered small units (U.S. Department of Agriculture, U.S. Department of the Interior, Range Seeding Equipment Committee 1965). Power requirements increase with height and density of brush. Brush stands generally recover in less than 5 years unless additional measures such as fire or herbicides are employed. Beating causes little soil disturbance or damage to understory species and is best completed during early growth periods for 2 consecutive years.

*Rotary Mower*

In contrast to the brush beater, the rotary mower consists of rotating knives attached to vertical shafts. Power is usually supplied by the power take-off. Once-over mowing does a complete job of reducing vegetative material to litter. Good kill of large, nonsprouting shrubs such as sagebrush is obtained, but seedlings and young plants are not always damaged. Like the beaters, the usefulness of rotary mowers is limited in rocky areas. Power requirements are higher than for beaters, but twice-over mowing is seldom needed (Larson 1980).

Rotary mowing 1 year prior to using herbicides proved to be an effective treatment on the Bridger-Teton National Forest, Wyoming, where esthetic considerations were critical. Costs for 1982 were estimated at $10 per acre ($25/ha) on abandoned farmland and other rock free terrain (U.S. Department of Agriculture, Forest Service, see footnote 1). Use of the rotary mower cannot be termed successful for sagebrush control on a long-term basis. However, depending on the objective, it may be considered a useful tool when control is required for less than 5 years.

*Moldboard Plow*

Plowing is probably the most effective mechanical method for maximum control of sagebrush as well as control of most other competing species. The moldboard plow can be used to good advantage on relatively level, rock-free soil. Because of its relatively high power requirement and slowness, the moldboard plow is more expensive to use than are disk-type plows. The moldboard plow requires approximately 20 hp (15kW) (drawbar) to plow a 42-inch (1.1-m) swath (Larson 1980).

*Wheatland Plow*

The wheatland plow is well adapted to relatively level sagebrush areas. It cannot be used on rocky sites without a high risk of damage. Nonsprouting sagebrush can be controlled when plowed at 2- to 4-inch (5- to 10-cm) depths. When sprouting plant species are to be controlled, plowing at 4- to 6-inch (10- to 15-cm) depths is needed. Even better results can be obtained by dragging sections of spiketooth harrows in tandem behind the plow. Harrowing is well worth the added cost in most cases. The second section of the harrow should be chained directly to the front section using a 2-ft (0.6-m) spacing. This arrangement allows the two sections to work independently and deposit root sections on the soil surface to dry in the sun.

Where control of cheatgrass (*Bromus tectorum*), bulbous bluegrass (*Poa bulbosa*), and similar herbaceous plants, as well as sagebrush and sprouting shrubs, are part of the objective, shallow plowing and harrowing early in the growing season and again during mid-season will provide good results. This adaptation can also be applied to other types of disk plows. Double plowing and harrowing with a properly adjusted wheatland plow should consistently provide over 90 percent control of all sagebrush (U.S. Department of Agriculture, Forest Service, see footnote 1).

*Tandem Disk Plow*

The offset disk plow is a tandem disk with the front section disks facing one way and the rear section disks facing the opposite direction. This arrangement double plows the area with the rear disks tracking in a line between the front disks. Frames may either be ridged or sectioned depending on the design. As with other disk plows, disks should be 24 to 28 inches (61 to 71 cm) in diameter to provide adequate tillage depth and clearance when used on rangeland.

Tandem disk plows obtain about the same degree of sagebrush control as the wheatland plow. Due to their heavy weight, they offer an advantage over the wheatland plow in heavy, tight soils, and on rough terrain. Tandem plows also have a distinct advantage over the wheatland plow where large amounts of herbaceous vegetation must be controlled. The heavy machine cuts and underturns the vegetation into the soil. Where double plowing is needed, the lighter weight wheatland plow has the advantage. A second plowing, later in the growing season, further reduced competitive plants resulting in better control of vegetation.

Tandem disk plows are easy to adjust and perform well over changing soil conditions. However, operators tend to allow these plows to work deeper than necessary, thus wasting power and time. Plummer and others (1955) recommended plowing to depths of 5 to 7 inches (13 to 18 cm) when controlling sprouting species such as rubber rabbitbrush (*Chrysothamnus nauseosus*). The Ashley National Forest has obtained good results by deep plowing using the Amco plow and spike tooth harrow combinations in removing a tall-dense stand of rubber rabbitbrush on deep mudstone shale deposits.

*Brushland Plow*

Due to the inability of the first wheatland plows, and most disk plows, to withstand work on most National Forest rangelands, the need for a more sturdy machine was soon recognized. Wheatland plows and disk plows built prior to the mid-1940's were not designed to handle rocky soils and heavy stands of brush. Frames and assemblies were almost ridged, lacked adequate clearance, and could not withstand the hidden rock outcrops and stumps.

The brushland plow was designed from an Australian "stump-jump plow" by the San Dimas Equipment Development Center. The plow consists of seven pairs of disks independently mounted on spring-loaded arms. This implement is useful for controlling shrubs on rough, rocky terrain (Larson 1980). Brushland plows as we know them today can be used in pairs and are reported to be more efficient in power requirements than wheatland plows of similar cutting widths. The heart of the brushland plow is the independent spring-loaded disk assemblies consisting of two disks. The front disk is 28 inches (71 cm) and the rear disk 24 inches (61 cm) in diameter. The two disks bolt solidly to a single axle mounted at an angle to the forward motion to allow the disks to scoop as they roll. Due to the difference in diameters, the rolling disks set up a slicing action that aids in cutting through plant material instead of rolling over it (Larson 1980).

The brushland plow weighs nearly 3.5 tons (3.2 metric tons), nearly double the weight of a wheatland plow of similar working width, yet less drawbar power is required to pull it. Control of sagebrush showed the brushland plow to provide about 90 percent control compared to wheatland and offset disk plows, which each gave about 75 percent control on the same site (Plummer and others 1955). Spike-tooth harrows attached to the brushland plow would be a worthwhile addition for control of sprouting species.

*Anchor Chains*

Three basic chains are available for use on sagebrush sites. The slick or unmodified chain is sometimes used but is largely ineffective unless individual links weigh 90 lb (41 kg) or more and sagebrush is large and brittle. Young or flexible plants are not effectively removed. Because of the difficulty of controlling brush, most chains have been modified into two basic designs.

Chambers (1967) described a chain modification generally known as the Ely chain. Steel rods approximately 18 inches (46 cm) long are welded across each chain link so that approximately 4-inch (10-cm) projections are at right angles to the link. Links of about 40 to 60 lb (18 to 27 kg) each with about 30 lb (14 kg) of light railroad rail are generally used. On some chains, old truck axles have been used and even new cold rolled steel. Ideally, the base would be cut from railroad rails in order to remove the potential for brush to catch and wrap around the chain. Tips of the projections should be hard surfaced with welding rods, such as Marquette No. 455. Marquette No. 7018 rod, 3/16-inch (0.47-cm) diameter, can be used to weld cross pieces to chain links.

Jensen (1969) described another chain modification known as the Dixie Sager. This chain used in combination with the Ely chain provides more effective control of sagebrush than either chain used alone. The Dixie Sager is more difficult to manufacture than the Ely chain because the rails are welded lengthwise to the rounded chain link, requiring about twice as much welding. Before attempting to weld on a surplus anchor chain, it should be used for chaining for a few hours to polish the links and remove all forms of corrosion. Rail sections should have the bottom flange completely removed, leaving the top of the rail to be welded to the link and the center part of the rail as a projection. The rail section should only be long enough that it can be solidly welded to the link, leaving nothing to catch and hold brush. All wear points should be hard surfaced to maintain approximately 4 inches (10 cm) projecting as a scarifier. The chain must be self cleaning and be kept reasonably free of brush to provide satisfactory brush control.

After numerous chainings on several National Forest in Utah, we have concluded that it is best to use two 150- to 200-hp (112- to 149-kW) crawler tractors. Approximately 45 ft (14 m) of medium-weight smooth chain with 1.5-inch (3.8-cm) diameter links is hooked to each tractor. To the ends of each smooth chain is attached a specially constructed swivel made from rebuilt track rollers from D-9 Caterpillar tractors. These heavy swivels remain close to the soil surface and are each attached to a 60-ft (18.3-m) section of Dixie Sager. The remaining ends of the Sager chains are attached to the ends of a 40-link section of Ely chain (U.S. Department of Agriculture, Forest Service, see footnote 1).

The two tractors attempt to operate nearly parallel to each other, pulling the 225 to 250 ft (69 to 76 m) of chain in an open V or U shape. The modified portions of chain slowly turn with a self-cleaning sawlike action as they slide over the soil surface. Swivels must be greased at least once each day. Maximum scarification and brush removal is obtained with the tractors operating close together. Scarification is greatly reduced if tractors operate more than 75 ft (23 m) apart. This maximum spacing should be specified in all contracts and strictly enforced. As a rule of thumb, the total chain length should exceed three times the spacing of the tractors as measured from drawbar pin to drawbar pin. The Dixie Sager does not work well in the center of the chain because it is more prone to roll than is the Ely chain. Only moderate sage control can be expected along the center of the chain, but nearly 90 percent control can be obtained along the two outer one-third sections of the swath, providing the chain is kept reasonably clean and the tractors do not exceed the optimum spacing of 75 ft (U.S. Department of Agriculture, Forest Service, see footnote 1).

As with other mechanical methods of sagebrush control, chaining is most effective on older, brittle plants and least effective on young or flexible plants. The anchor chain is probably the least understood tool commonly used for control of sagebrush and juniper (*Juniperus* spp.). The difference between obtaining a good kill of target plants and project failures is often the result of one or more of the following considerations: (1) objectives of the project, (2) project supervision, (3) tractor spacing, (4) chain design, or (5) chain repair and maintenance.

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## Chemical Plant Control

**Ray Dalen,** *Chairman*
(Reported by Dan W. McKenzie, Forest Service, San Dimas, CA)

A handbook on aerial herbicide application is being prepared and is in draft form. Some updating and review is awaiting funding and the issuing of a purchase order to the University of California at Davis for work to be done by Dr. Norman B. Akesson.

## Foam Marking Systems for Rangeland Sprayers

By Maurice R. Gebhardt, Agricultural Research Service, Columbia, MO; Allen Torell, Utah State University, Logan, UT; James A. Young and Raymond A. Evans, Agricultural Research Service, Reno, NV
(Presented by Dan W. McKenzie, Forest Service, San Dimas, CA)

### Introduction

Numerous foam marking systems are commercially available and in general use in intensive agriculture in the Midwest and Great Plains States. However, on the rangelands of the West, range managers may not be familiar with these systems. When applying herbicides to rangelands with a ground sprayer, a marking system is very valuable in avoiding skips and overlaps, especially in undulating terrain or when spraying tall brush.

The authors have assembled a prototype ground sprayer for use on sagebrush (*Artemisia*) rangeland and equipped it with a foam marking system (fig. 1). (See also 37th VREW annual report, p. 29.) This foam marking system is very helpful in avoiding skips and overlaps when applying herbicides. This system costs about $1,000 and is estimated to have a benefit/cost ratio of over 28:1.

Figure 1.—Prototype sagebrush sprayer.

### Need for Ground Sprayer

The large areas, and the difficulty in pulling a ground sprayer through rocks, brush, gullies, and on steep topography has generally limited the application of herbicides on rangelands to aerial spraying. There is no question about the relative ease of aerial vs. ground application of herbicides on most sagebrush range sites. However, Government agencies and private landowners who wish to treat relatively small areas in a systematic annual improvement may have difficulty in obtaining custom aerial applicators at reasonable cost. This difficulty is due to the remoteness of most rangelands from areas of intensive agriculture and the additional cost of ferrying aircraft to the spray site.

Conflicts in timing of the application of herbicides to rangelands vs. more lucrative pesticide application to row crops near the aerial applicator's base of operations also makes it difficult to attract aerial applicators. If the spray job is 1,000 acres or more, the job will attract a number of applicators. However, if the job is only 50 acres and at a very remote site, there may be no aerial applicator interested, and it may, therefore, be more feasible and necessary to apply the herbicide with ground equipment.

### Operation of Ground Sprayers

Application of herbicides for sagebrush control by ground sprayers can be relatively fast, efficient, and cost-effective provided the proper equipment and a knowledgeable and experienced operator is used. Proper equipment includes a ground sprayer, nurse tank, and pumps to transfer water and spray material.

To do a good job, the sprayer operator must be able to tell where he has sprayed. Ground sprayer operators when spraying rangeland here have always had a problem of knowing where they have sprayed. This problem is of particular concern when spraying sagebrush on rangelands. Range sites are rarely rectangular and even if the area to be treated is rectangular, it is difficult to maintain a straight path while dodging rocks and crossing gullies. Sprayer operators find it almost impossible to maintain orientation as they traverse cone-shaped alluvial fans that often characterize sagebrush rangelands.

Skips or overlaps in herbicide application resulting from loss of orientation by the sprayer operator are a concern because of poor brush control in the skipped areas and added costs of herbicides and spraying time when double-coverage occurs. Soil-active herbicides used for controlling cheatgrass (*Bromus tectorum*) require that there be no overlaps in application since excessive residues in the soil can prevent later forage seedling establishment and plant growth.

Because of the remote site and difficulties in obtaining good clean water, the application of herbicides must be made using low-carrier rates. Ten gal/acre total volume (herbicide plus carrier) were used by the prototype sprayer. These low-carrier rates almost preclude the use of a dye in the carrier because

so little spray material is used. At times, the dyed sprays can be seen deposited on cow chips or light-colored rocks; however, in dense sagebrush, the brush must be more clearly marked for the marking system to be effective.

**Foam Marking Systems**

There are several manufacturers of foam marking systems. These systems usually consist of a low-pressure tank that serves as a reservoir for the foam concentrate and its carrier, which is normally water, an air compressor for an air source, plumbing to distribute the foam, and a control system.

Foam is generated within the compressed air/water tank by the injection of air through a nozzle at the bottom of the tank. Foam is formed at the water surface as air rises and breaks free. The foam moves with the air as it escapes through the distribution tubes and valves and out the foam nozzles or emitters on the ends of the booms. The tubes that carry the foam from the tank to the nozzles must be large enough to carry sufficient foam to mark adequately. Often, 1-inch (2.5 cm) ID PVC flexible tubing is used to distribute the foam. The foam nozzle or emitter often consists of an expanded tube about 5-inch-diameter (12.5 cm) that is attached to a 90-degree elbow (fig. 2). Foam collects inside the nozzle until enough accumulates to fall out. As the sprayer traverses the field, foam globs are dropped on the brush. These globs of white foam are very good markers when spraying brush because they will remain on the brush for 15 minutes and can easily be seen from a distance.

Figure 2.—Foam emitter nozzle. These hang from boom ends. Enlarged tip accumulates a glob of foam which, when falls, will hang on brush. Elongated neck of nozzle is flexible and will not be damaged if boom drops into brush.

Only one nozzle needs to be operated at a time. The nozzle on the opposite side can be used as a guide. Solenoid valves control the foam nozzles. Switches for the solenoid valves are mounted near the tractor operator. The operator can reduce the frequency of foam marks by turning on and off the control valves; for it may not be necessary for the foam to be deposited as frequently in some fields as in others, depending on the terrain and brush characteristics.

An air compressor driven by a 12-volt dc electric motor supplies compressed air to the foam marker system. The foam marker tank contains 40 gallons of foam concentrate and water solution. This is enough to last for three, 300-gallon tankloads of herbicide or the spraying of up to 90 acres before refilling the foam generator when spraying at 10 gal/acre. The amount actually required for a given field depends on the site and the experience and skill of the operator, as foam can be used only when needed for proper orientation since the operator can turn the marker on and off.

**Foam Marking Concentrates**

Foam marking concentrates are available from commercial suppliers. Some of these concentrates are nonphytotoxic while others may produce some injury symptoms to plants. Instructions supplied with the concentrate and mixing ratios shown on the label should be followed. These ratios may have to be adjusted in cool weather when foams are hard to produce. Experimentation with mixing ratios under specific field conditions is suggested. Hardness of the water has large effect on the performance of foam concentrates. Some suppliers sell a water softener to use with the foam concentrate. The normal mix ratio is about 1 gallon of concentrate to 40 gallons of water.

**Benefit/Cost Analysis of Foam Marker System**

The cost of the foam marker solution for average sagebrush range sites is about 12 cents per acre. When the cost of the investment in the foam generator and distribution system is included, the cost increases to about 23 cents per acre (table 1).

Benefits from the foam marker system are large, relative to the 23 cents per acre cost. Spraying costs are estimated to be reduced by $1.93 per acre because of less herbicide used and reduced spraying time. This cost savings alone would more than justify the use of the foam marker system.

Because the foam marker system would eliminate most skips and thus areas of poor brush kill, use of the marker system could also be expected to result in additional forage production. By using the foam marker when spraying, a forage benefit of 3.5 AUM's per year for 10 years for a 40-acre plot located on big sagebrush range sites has been estimated. This represents a .088 AUM benefit per acre.

Total per acre benefits of the foam marker system are estimated at $6.48. After the 23 cents per acre foam marker operating and investment cost is subtracted, the net present value of using the foam marker is estimated to be $6.25 per acre. The benfit/cost ratio is then estimated at over 28:1.

The foam marker system is a very economical way to improve sagebrush kill while spraying. Just as importantly, the needed investment is relatively small—approximately $1,000 for tank, compressor, and foam distribution system.

Table 1.—*Costs and benefits/acre from operating sprayer foam marker system*

| | |
|---|---|
| **Benefits** | |
| Cost Savings | |
| .45 lb less 2,4-D x $2.50/lb | $1.13 |
| .224 lb less Atrazine x $3.00/lb | .68 |
| Less sprayer operating time and use | .12 |
| Increased forage | |
| .088 AUM's x $8.36/AUM[1] | .74 |
| Total first year cost savings | 1.93 |
| Total forage benefits (present value of $1.74 for 10 years, 10%) | 4.55 |
| **Total discounted benefits/acre** | **$6.48** |
| **Costs** | |
| Additional spraying labor | $ .00 |
| Additional fuel | .00 |
| Additional repairs | .03 |
| Foam | .12 |
| Depreciation (36 cents/hr x .208 hours) | .07 |
| Interest (38 cents/hr x .208 hours) | .01 |
| **Total cost/acre** | **$ .23** |
| **Benefit/Cost Analysis** | |
| Total discounted benefits/acre | $6.48 |
| Total foam applicator costs/acre | .23 |
| Net Present Value/Acre | $6.25 |
| **Benefit/cost ratio (6.48/23 cents)** | **28.2:1** |

[1]Reflects the average lease rate paid for pasturing cattle on privately owned, nonirrigated lands during 1982 (USDA-ARS 1982).

## Structural Range Improvements

**Billy H. Hardman,** *Chairman*

The major new item for this workgroup is a project proposal for a Structural Range Improvement Handbook. This proposal is at the Missoula Equipment Development Center and hopefully will be underway in fiscal year 1985 with completion in fiscal year 1986. The collating of information into one nationwide handbook or catalog should be a very usable tool and a big time saver, since the handbooks are now developed on a State or regional basis by each agency.

### Low-Cost Diagonal Fence Strainer

By Dan W. McKenzie, Forest Service, San Dimas, CA, and W.F. (Bill) Currier, Forest Service (ret.), Albuquerque, NM

Corner, line, and gate or fence end braces (or strainers) are an important part of any fence. With the use of high-tensile, smooth wire, these strainers are of even greater importance because of the necessity of maintaining the complete fence at the recommended tension. In recent years, the horizontal fence strainer (fig. 1), (or the double-horizontal fence strainer), has been accepted as the standard and strongest fence strainer design. However, another fence strainer design, known as a diagonal fence strainer (fig. 2), is structurally equal to the horizontal fence strainer, but is much less costly to install. It requires one less post and only about half the labor to install as the horizontal fence strainer. A diagonal fence strainer is equal in strength and holding force to a horizontal strainer. It has the same lifting force on the corner post as a horizontal strainer of the same size. On a high-tensile, smooth-wire fence, one diagonal strainer (fig. 3) can be used for a corner in place of the currently used two horizontal braces (fig. 4).

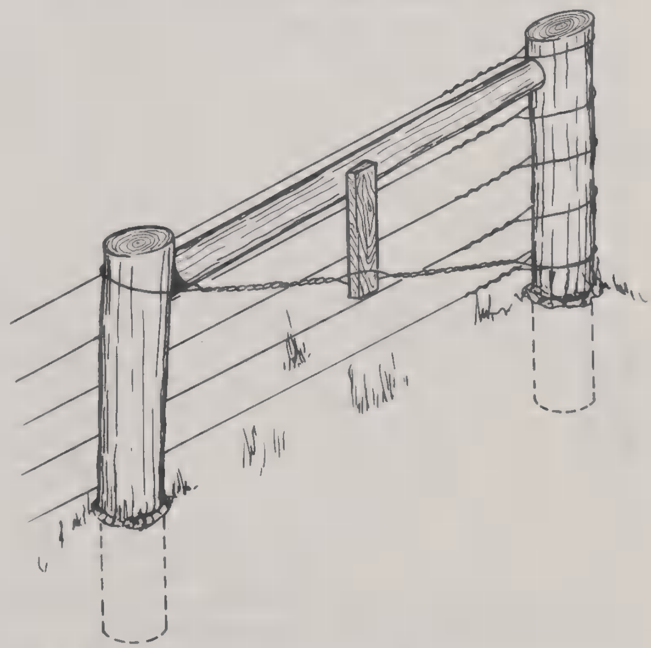


Figure 1.—Horizontal gate or fence end strainer.

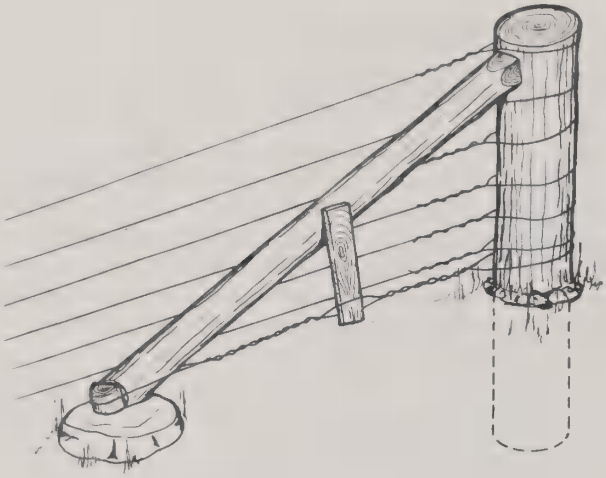


Figure 2.—Diagonal gate or fence end strainer.

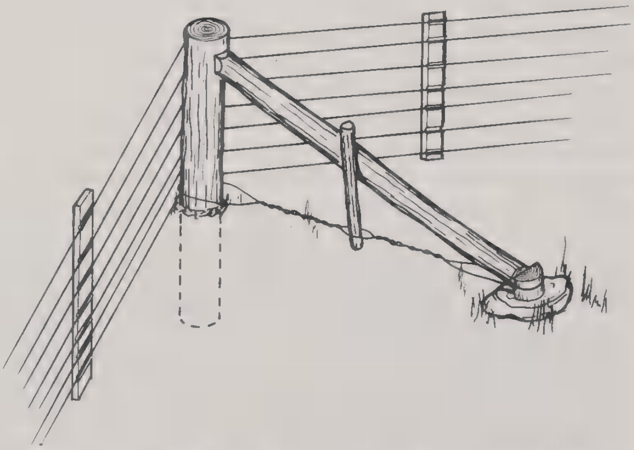


Figure 3.—The use of one diagonal strainer for a corner brace on a high-tensile, smooth-wire fence. In this design, the high-tensile, smooth wire must be bent around the corner and must not be tied to the corner post.

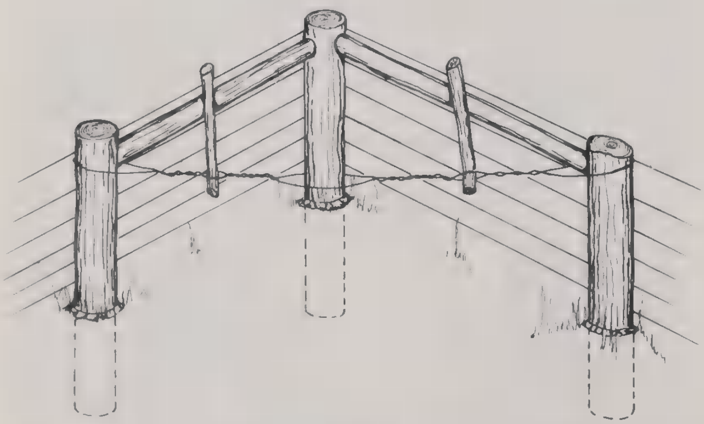


Figure 4.—Two-horizontal strainer corner brace can be replaced by a single diagonal strainer or by two diagonal strainers.

The single strainer could be undesirable for livestock. Cattle could straddle the brace or go on both sides and calves can go under the brace. If this is a problem, use two diagonal strainers running at the same angle as the fence (fig. 5). A single diagonal strainer is not recommended for corners less than 90 degrees. For corners less than 90 degrees, use two diagonal strainers. A single diagonal strainer works very well for corners greater than 90 degrees and should be used.

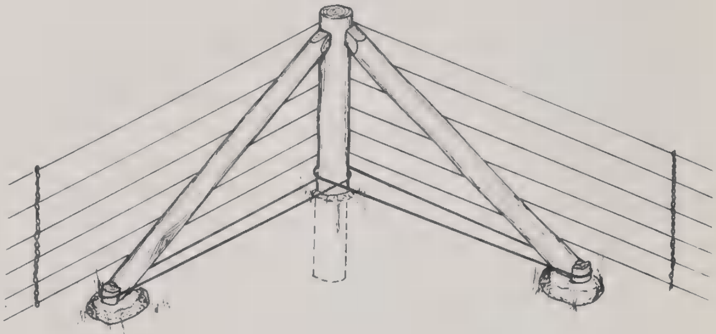


Figure 5.—Two diagonal strainer corner braces.

In designing and installing a diagonal brace or strainer, several principles should be kept in mine:

1. Make the diagonal (horizontal as well) brace as long as possible (table 1).

Table 1.—*Practical lengths for compression members of diagonal (or horizontal) fence strainers*

| Pipe size (in) | Wood diameter[1] (in) | Practical length (ft) | Allowable length (ft) |
|---|---|---|---|
| 2 | | 8 | 10 |
| 2½ | | 9½ | 12 |
| 3 | | 12 | 14½ |
| 3½ | | 13½ | 17 |
| 4 | | 15 | 19 |
| | 3 | 7½ | |
| | 4 | 10 | |
| | 5 | 12½ | |
| | 6 | 15 | |
| | 7 | 17½ | |
| | 8 | 20 | |

[1] Diameter at center and straight length assumed.

2. Be sure that the end of the diagonal brace in contact with the ground is free to move forward and is not blocked by a stake or post. *The reason*: When the end of the diagonal bears against a stake or post and is not free to move, one-half to two-thirds of the total fence tension can be transmitted to the stake or post. This reduces the ability of the strainer to resist pullout (failure).

3. The diagonal brace can break against the corner post in any location from the middle of the post to the top. However, probably the best place to have the diagonal brace contact the corner post is at the top. *The reason:* The maximum bending moment of the corner post (located at ground level where the brace wire is attached to the corner post) is the same whether the diagonal brace bears at the top or middle of the corner post. The loading in the diagonal brace (compression) and lower brace wire (tension) will be double when the diagonal brace bears against the middle of the corner post as compared to when the diagonal brace bears against the top of the corner post. In the diagonal strainer, when the diagonal brace bears against the top of the post, the tension force in the wire brace is about equal to or a little less than the total tension in the fence. The length of the diagonal has no effect on this tension force. In the horizontal strainer, the tension force in the wire brace is about equal to or a little more than the total tension in the fence. The length of the top brace of the horizontal strainer does effect and cause the tension force in the wire brace of the horizontal strainer to vary, but only to a relatively limited amount (15 to 25 percent). The longer the horizontal strainer, the lower the tension force in the wire brace. The tension force of the wire brace of a horizontal strainer is higher (by 5 to 15 percent) than the tension force of the wire brace of a diagonal strainer of equal length.

4. When installing a diagonal strainer, the corner post should be set first, then the diagonal brace installed, then the bottom holding wire brace installed, and then the wires attached and tensioned. If this procedure is followed, the lower wire brace will not have to be twisted to tighten.

5. The diameter of the corner post used should be as large as possible.

6. If one diagonal strainer will not hold the fence tension, a second diagonal strainer should be installed (fig. 6), with each strainer taking half the tension of the fence.

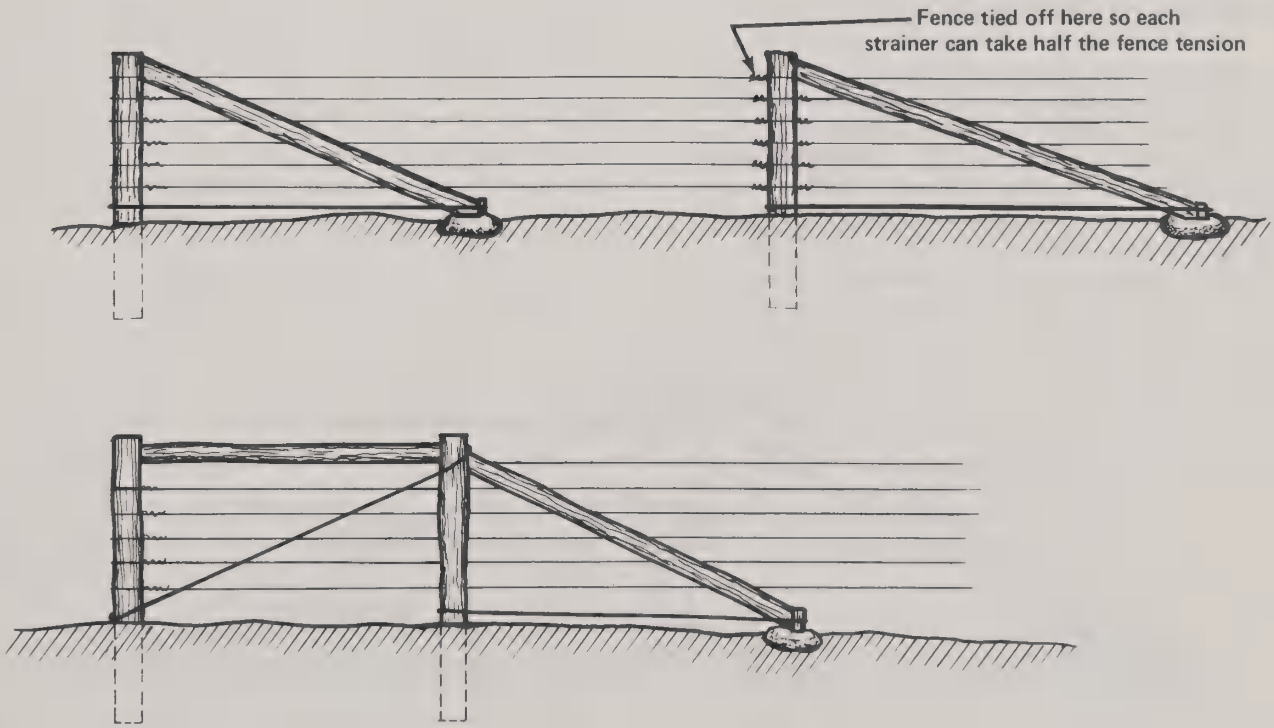



Figure 6.—Use of two diagonal strainers for holding in soft soil. Also, one horizontal and one diagonal strainer could also be used as shown. Each of the diagonal strainers takes half of the tension in the fence; therefore, the fence must be tied off at each diagonal strainer.

In examining the diagonal and horizontal strainer, it may, at first, be very difficult to realize that these two strainer arrangements are structurally equal. However, upon complete examination and the determining of the forces in each of these structures, it will be found that the reaction of the ground on the strainer is the same (fig. 7).

These reactions are a force ($F_1$) horizontal to the ground (below the ground) pushing on the corner post in reaction to the tension in the fence. A second force ($F_2$) is an upward force on the end of the diagonal brace resting on the ground, and also an upward force ($F_2$) on the second post of the horizontal strainer. There is also a downward-pulling force ($F_3$) exerted by the ground on the corner post to hold it in the ground. The greater the fence tension force is with either the horizontal strainer or diagonal strainer, the greater this force ($F_3$) can be. By making the diagonal as long as possible or, for that matter, the top of the horizontal strainer as long as possible, the force tending to pull the corner post out of the ground is reduced.

When using the diagonal strainer as a line brace (fig. 8), care must be exercised not to overtension the brace wires. When the diagonal is used as a line strainer, and the brace wires are overtensioned, the vertical post can be jacked out of the ground. For this reason, the diagonal strainer may not be as good a line brace as a horizontal brace with two brace wires. However, when high-tensile, smooth wire is used, the need for line braces is reduced or eliminated.

There is an old German proverb that says, "Everything that is good, is probably not new, and everything that is new, is probably not good." This proverb applies to the diagonal strainer. The diagonal strainer design is not new as it was in use 50 years ago in South Dakota. It has also been used in eastern Washington and, to a limited extent, in New Zealand.

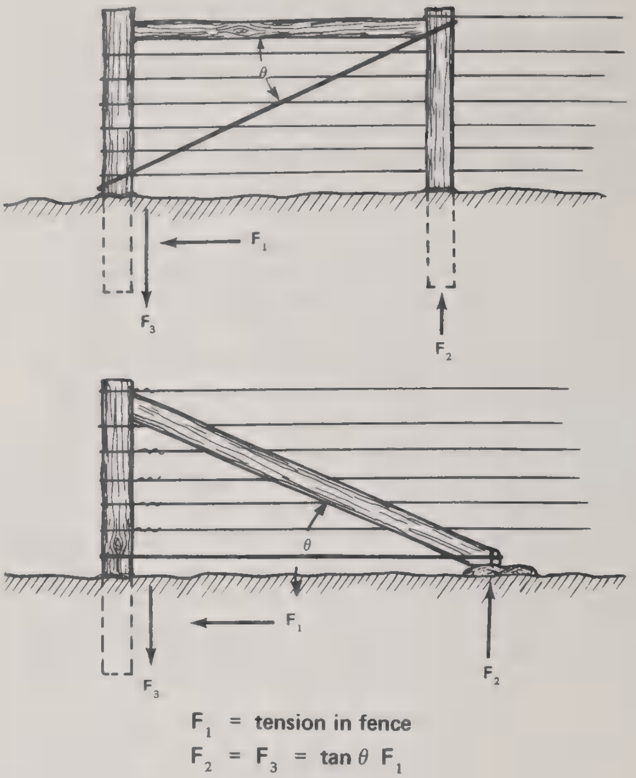



Figure 7.—Reaction of the ground on horizontal and diagonal strainers.

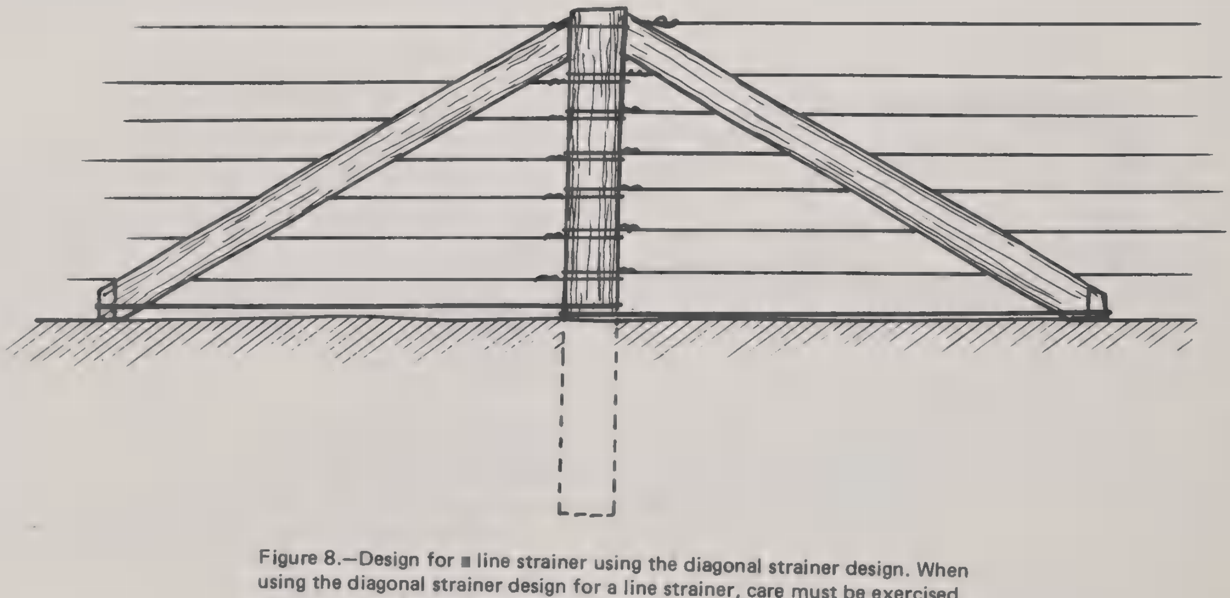


Figure 8.—Design for a line strainer using the diagonal strainer design. When using the diagonal strainer design for a line strainer, care must be exercised not to overtension the brace wire and jack the post out of the ground.

## Range Water Systems Improvements Project ED&T OE01D40

By Dan W. McKenzie, Forest Service, San Dimas, CA

The goals of this project are to improve range water supplies and systems for pumping and handling range water. The objectives, as determined by the Structural Range Improvements Workgroup are to: (1) Investigate and develop systems for inhibiting or preventing stock water tanks from freezing; (2) investigate and develop solar water pumping systems as alternatives to the conventional windmill.

### Preventing Stock Water Tanks from Freezing

The San Dimas Equipment Development Center has investigated methods and techniques to keep livestock water tanks from icing over and preventing animals from drinking and has distributed a report, "Preventing Livestock Water from Freezing." Conclusions and recommendations from this report are:

*Conclusion*

Our survey of available equipment for, and approaches to, preventing livestock water from freezing (see table 1) shows that a rancher or farmer should be able to avoid manual ice chopping at remote livestock watering sites by using one of the methods, marketed or proposed, discussed in this report. However, it may not be practical nor economical to do so. Specifically:

1. Use of insulated covers and applying insulation to the sides of stock tanks should be considered for ice-free stock water tanks.

2. The propane bubbler seems the most simple and cost-effective freeze-prevention technique in climates that are not extreme.

3. Photovoltaic-powered, water-circulation pumps appear to be practical and, because of their low cost, should be further investigated.

4. Mass-insulated tanks are probably one of the simplest and most certain of the approaches presented for preventing freezing in livestock water tanks.

5. Heat pipes are an alternative to the propane bubbler that do not require a nonrenewable energy source. In colder climates than the New Mexico area, the rate of heat transfer may not be sufficient to prevent freezing. However, the technique shows promise, appears economical, and is considered worthy of further evaluation.

6. Photovoltaic cells to power an electric coil heater for freeze prevention in stock tanks is impractical because of the high cost of the photovoltaic cells. However, if commercial electric power is available, the electric coil heater for freeze prevention in stock tanks is very practical.

7. Solar-heated (greenhouse effect), water-immersed, insulated tank; within a stock tank are considered excellent.

8. In-the-ground insulated tanks with access door may be impractical because of the swinging doors; however, if the design were modified with curtains, this problem may be reduced or eliminated.

9. Thermosiphon with a flat-plate collector system appears to be impractical unless just the right location is available.

10. The flat-plate collector systems with photovoltaics-powered pump approach is good although possibly too expensive for consideration at the present time—since the cost of photovoltaics is approximately $10 per peak watt.

11. A small solar pond solar collector, constructed for preventing a stock tank from freezing, would probably not be cost-effective—particularly when considering the high cost of photovoltaics needed to power a pump to move the heat transfer fluid from the pond to the heat exchanger in the stock tank. Maintenance requirements of the solar pond would also be a problem.

*Recommendations*

Only the following is proposed for Forest Service equipment development in the area of preventing livestock water and livestock water tanks from freezing: An investigation of photovoltaic-powered, water-circulation pumps and the Solar Energy Research Institute water-immersed insulated box. Also, on an opportunity basis, the market search should continue and any new information uncovered should be presented in future VREW annual reports.

If additional equipment development is determined to be necessary in the area of preventing livestock water and livestock tanks from freezing, an agricultural college in an area of frequent below-freezing temperatures should be placed under contract to conduct well-controlled experiments with a number of stock tanks having different types of freeze-prevention systems and with sufficient instrumentation to measure the system performances. The systems should be monitored to understand their operation and much data should be collected on flow rates, temperature stratification, heat loss, heat gain from the ground, solar gain, evaporation losses, source water temperature, etc. In this way, systems for preventing livestock water from freezing could be developed, tested, evaluated, and optimized.

## Table 1. Livestock water freeze-prevention devices discovered in survey

| Approach | Device | Source | Initial cost | Advantages | Disadvantages | Comments |
|---|---|---|---|---|---|---|
| Circulation of unfrozen water below ice layer | Propane gas bubbler | Stockman's Nat'l. Supply Co., Inc., Pueblo, CO | Under $100. | Dependable, low-cost, efficient | New tank of propane every 3 mo.; annual cleaning & storage | Install at bottom of tank or pond |
| | Wind-driven propeller: the Pondmaster | Wadler Mfg., Galena, KS | $150 to $300, depending on size | Free energy source | Dependent on wind | Not recommended for stock tanks; recommended for ponds and lakes |
| | Photovoltaic-powered water circulation pump | William Lamb Co., No. Hollywood, CA | $25 for pump, $350 for photovoltaic panel | Free energy source | Dependent on sun; $350 for solar panel | Proposed |
| Mass-insulation water tanks | Culvert tanks | Rosecoe Steel & Culvert, Billings, MT | $1,700 (typ.): see table 2; accessories & installation are extra | Dependable, passive | Installation costs | Self-contained |
| | Concrete tanks | Dale Greenwood, Cartwright, ND | Over $1,000 | Dependable—even when -30° F (-34° C) over long period, rugged, passive | Installation costs | Not commercially available; self-contained |
| | Steel tanks | Henry B. Davis, Petersburg, VA | $350; installation extra | Dependable, passive | Installation costs | Commercially available; self-contained |
| Heat pipe metallic tanks | Heat tanks | Frederick J. Sparber, Belen, NM | $40 ea. tank; accessories & installation are extra | Dependable, passive | Do-it-yourself project | U.S. patent No. 3,943,889; not commercially available |
| Solar photovoltaics | Water-circulation pump | William Lamb Co., No. Hollywood, CA | $25, not including accessories or panel | Free energy source | Dependent on sun; $350 for solar panel | Proposed |
| | Electric coil heater | Stockman's Nat'l. Supply Co., Inc. Pueblo, CO | Under $30, not including accessories | Free energy source | Dependent on sun; $15,000 for solar panel | Proposed; not practical because of cost |
| Solar greenhouse effect | Solar-heated, water-immersed insulated tank | Spencer B. Sitter, Santa Fe, NM | $1,000; accessories & installation extra | Free energy source, passive | Dependent on sun | U.S. patent No. 4,108,156; not commercially available |
| | | Solar Energy Research Institute (SERI) | $600 | Free energy source, passive, simple, low-cost | Dependent on sun | Proposed |
| | In-the-ground insulated tank | Randall L. DeGroot Columbia, MO | Not available | Free energy source, passive | Dependent on sun | Not commercially available—only proposed |
| Solar collector flat-plate thermosiphon | Flat-plate collector using thermosiphon | Components commercially available | $500; accessories & installation extra | Free energy source | Dependent on sun | May not be practical because flat-plate collector must be below heat exchanger |
| Solar collector with photovoltaics | Active flat-plate collector with electric pump and heat exchanger | Most components commercially available | $1,900 estimate; accessories & installation extra | Free energy source | Dependent on sun | Proposed system |
| | Active flat-plate collector with electric pump and heat exchanger in water-immersed insulated box | Most components commercially available | $2,500 estimate | Free energy source | Dependent on sun | Proposed system |
| | Solar pond with electric pump | Undergoing research at various institutions | Not known | Free energy source | Needs large area | Not practical at this time |
| Insulation covers for top and side insulation | Swimming pool type covers; side insulation | Commercially available | $200–$600 | Passive | Installation and maintenance may be problems | Suggested by Solar Energy Research Institute |

### Solar Water Pumping Systems

The Range Water Systems Improvements project is very timely because of the amount of ongoing research and development work in water pumping and the new equipment and techniques becoming available. The conventional windmill is a functional, reliable, long-lasting, economical range water pumping system. Functional and economical alternatives are not easy to develop. However, some of the new water pumping systems and equipment under development, under some circumstances, have the potential to be cost-effective alternatives to the conventional windmill.

Three categories of equipment may offer alternatives to the conventional windmill: (1) Improved or new windmills; (2) photovoltaic-powered pumping systems; (3) Solar-thermal pumping systems.

In the improved and new windmill and photovoltaic categories, considerable research and development are underway with promising new equipment being developed. In the solar-thermal category, demonstration equipment is still being operated, but little, if any, new equipment is being produced.

### Improved or New Windmills

The conventional multibladed windmill, being a functional, reliable, long-lasting, economical range water pumping system, has been in use for more than 125 years. During this time, the windmill has undergone continual improvement: backgearing for deeper pumping; enclosed gearing requiring oiling annually instead of weekly; improved sail construction and design; and improved automatic regulation. It is not an easy product to improve or replace. However, work continues on improvements to the conventional windmill and the development of new designs. New improvements and new designs learned of, or under development, related to windmills are:

1. Fully counterbalanced windmill.
2. Spring-counterbalanced windmill.
3. Cam-operated windmill.
4. Hydraulic system, which replaces the pump rods of a conventional windmill.
5. Automatic stroke control for a conventional windmill.
6. Automatic stroke control for a three-bladed wind turbine.
7. Electric wind ac generator powering an ac submersible pump.
8. Electric wind dc generator powering a dc submersible pump.
9. Windmill-driven air compressor operating an air lift pump.
10. Long-life well cylinder.
11. Performance modeling and testing of windmills.

### Fully Counterbalanced Windmill

In a fully counterbalanced windmill, one-half the pumping work is done on the upstroke and one-half on the downstroke. On the uncounterbalanced windmill, all the pumping work is done on the upstroke plus lifting the pump sucker rods. Fully counterbalancing a windmill allows the windmill to start and pump water at lower windspeeds than a windmill that is not counterbalanced.

In a fully counterbalanced windmill, all the weight of the pump rods, one-half the water weight, and one-half the friction forces in the pump and stuffing box are counterbalanced by counterweights. This results in the starting torque being reduced to about 33 percent (with a 1-7/8-inch cylinder, 3/4-inch, airtight, hollow-steel rod, and assuming a pump mechanical efficiency of 70 percent) as compared to an uncounterbalanced windmill. As the torque developed by a windmill is approximately proportional to the square of the windspeed, and if a fully counterbalanced windmill will start in a 7-mph wind, it will take a 12.2-mph wind to start a conventional or uncounterbalanced windmill.

In an extensive test of a fully counterbalanced windmill and an uncounterbalanced windmill set side-by-side (75 ft apart) on the Navajo Indian Reservation near Window Rock, AZ, the fully counterbalanced windmill pumped substantially more water (13 times) at windspeeds below 10 mph than the conventional (uncounterbalanced) windmill; and at windspeeds above 10 mph, 32 percent more water was pumped by the fully counterbalanced windmill.

A fully counterbalanced windmill is available, in a 21-ft size only, from the Wind Baron Corp., 3702 West Buckeye Rd., Phoenix, AZ 85009, (602) 269-6900.

### Spring-Counterbalanced Windmill

The Bureau of Land Management (BLM), Vale District, OR, has developed a method of spring counterbalancing conventional multibladed windmills so they will start and run at lower windspeeds. Extension springs, 48 inches in length and 2 inches in diameter, are attached at the top of the tower and the free end is connected to the pump pole or red rod. Up to four springs have been used in deep wells.

The Vale District uses a scale made from a hydraulic-cylinder and pressure gage to determine the upstroke and downstroke loadings. The upstroke loading is the total weight of the pump rods, water column, and friction forces. The downstroke loading is the weight of the pump rods minus a small friction force. The counterbalance needed is the downstroke loading plus one-half the difference between the downstroke and upstroke loadings. The number of springs required can now be determined (generally two to four) in that each spring will counterbalance about 100 lb. The springs are hooked to the tower near the top. A bracket is attached to the pump pole to which the free end of the springs is hooked. The springs used by the Vale District are from a New Holland bailwagon (1046 or 1048), part number 510397, costing $63.73 each.

On the Aermotor windmills, the Vale District also replaces the main support friction bearing on which the millhead rests with a roller bearing so the mill will turn more easily into a light wind. On the Dempster windmill, the main support bearing does not have to be replaced because it is already a ball bearing.

Spring counterbalance in excess of three-quarters of the weight of the windmill should not be used.

The approximate weights of windmills are:

| Size (ft) | Weight (lb) | Three-quarters of weight (lb) |
|---|---|---|
| 6 | 215 | 160 |
| 8 | 370 | 275 |
| 10 | 665 | 500 |
| 12 | 1,130 | 847 |
| 14 | 1,781 | 1,300 |
| 16 | 2,508 | 1,800 |

The statement has been made about the BLM Vale method of spring counterbalancing that the conventional windmill is not designed to take loading on the downstroke and, if a windmill is loaded on the downstroke, accelerated and unusual wear will result. In normal operation, windmills are loaded on the downstroke (the weight of the pump rods), and the Vale District reports no accelerated or unusual wear.

**Cam-Operated Windmill**

In a cam-operated windmill, the lift cam is designed so the time of the lift stroke is longer than the time of the down or return stroke. When a cam mechanism is used in a windmill, the starting torque is reduced, allowing the windmill to start pumping water at lower windspeeds than a conventional windmill. In a cam-operated windmill with three-quarters of the pumping cycle time used for the lifting stroke, and one-quarter of the pumping cycle time used for the return stroke, the starting torque is reduced to 42 percent (with 1-7/8-inch cylinder, ¾-inch airtight, hollow-steel rod, and assuming a pump mechanical efficiency of 70 percent) of the starting torque of a conventional windmill. If all the pump rod weight were counterbalanced, the starting torque would be reduced to 28 percent of the starting torque required to start a conventional windmill. However, on a cam-equipped windmill, the pump rod cannot be 100 percent counterbalanced. If the pump rod were 100 percent counterbalanced, it would not return. If it is possible to counterbalance up to 70 percent of the pump rod, the starting torque would be reduced to 32 percent. As the torque developed by a windmill is approximately proportional to the square of the windspeed, and if a cam-operated windmill with a three-quarter lift time cam will start in a 7 mph wind, it will take a 10.8 mph wind to start a conventional windmill. If 70 percent of the pump rod weight were counterbalanced, and the cam windmill will start in a 7-mph wind, it would take a 12.4-mph wind to start a conventional windmill. At windspeeds above starting windspeed, where both the cam and conventional windmill are operating well, performance will be about equal. Limited production models of cam-operated windmills have been produced by Wind Energy Unlimited, Inc., 2527 North Carson St., Suite 205, Carson City, NV 89702, (702) 883-9303 or (805) 248-6023.

**Hydraulic System to Replace Pumping Rods**

A firm in Texas is developing a hydraulic system to replace the pumping rods of a conventional windmill. The windmill is connected to a well-type cylinder located at ground level. The output of this well cylinder (water under pressure) is pumped down the well to operate a cylinder pump. The advantages seen for this hydraulic system are: (1) The water source does not have to be directly below the windmill. (2) It is lightweight and can be quickly removed from a normal depth well by hand. (3) The unit will start and pump water in lighter winds than a conventional pump rod windmill. The reason given for being able to start and pump water in lighter winds is because the windmill does not have to lift the weight of the pump rods on the first stroke; however, due to the mechanical efficiency (force efficiency) of about 70 percent for each of the two additional well-type cylinders in the power train, they will probably more than negate the advantage of eliminating the pump-rod weight.

For more information, contact W.L. Hydraulics, 10203 Kotzebue, Suite 106, San Antonio, TX 78217, (512) 654-1412.

**Automatic Stroke Control for Conventional Windmills**

The power in the wind is approximately proportional to the cube of the windspeed. However, the conventional rod and cylinder pump used on the conventional windmill can only absorb power approximately proportional to a function of the windspeed when in the windmill operating range. If the pumping mechanism could absorb power approximately proportional to the cube of the windspeed, the windmill could pump much more water.

Don Avery, mechanical engineering professor emeritus of the University of Hawaii, has developed and validated an automatic stroke control device for use with a conventional windmill that allows a conventional windmill pump to absorb power approximately proportional to the cube of the windspeed. This device automatically changes the stroke of the well cylinder to match the level of energy in the wind (the length of the pump stroke is changed proportional to windspeed squared). This results in the volume of water pumped in relation to windspeed following approximately the same cubic relationship as the level of energy in the wind. If the windspeed doubles, theoretically eight times more water will be pumped, or four times more water than a conventional windmill without a stroke-control device.

Actually water pumped is somewhat less than four times because the water pumped by a windmill without a stroke-control device is about proportional to one and one-quarter times (or more) windspeed, and for a windmill with a stroke control, the water pumped will be less than proportional to the cube of the windspeed because of losses. Nevertheless, a great amount more water will be pumped with a windmill equipped with a well-functioning stroke-control device than a windmill without.

Computer studies done by VITA (Volunteers in Technical Assistance) indicate that twice as much water can be pumped with a windmill with a stroke control as a windmill without a stroke control or the windmill can be one-half the size when equipped with a stroke-control device as compared to a windmill not equipped with a stroke-control device. This would result in a windmill cost reduction of one-third or more, even when adding in the cost of a stroke-control device.

Also, a windmill equipped with a stroke-control device will start and pump water at lower windspeeds than a conventional windmill without a stroke-control device. The stroke-control device that Professor Avery has developed and validated will vary the stroke from 3 to 16 inches. Discussions are underway for the manufacture of the device as a kit for the conventional windmill. For more information, contact Don Avery, 45-437 Akimala St., Keneohe, HI 96744, (808) 247-1909.

**Automatic Stroke Control for a Three-Bladed Wind Turbine**

Prof. Avery has also developed and validated an automatic stroke-control device for a three-bladed electric generating-type wind turbine. The development model used a 25-ft-diameter rotor and the stroke varied from zero to 27 inches. The advantage of this device over the device developed for the conventional windmill is that a more efficient (30 percent for conventional multibladed windmills and about 40 or 45 percent for a three-bladed wind turbine) and less costly wind turbine can be used because the stroke will go to zero, allowing the three-bladed wind turbine to start.

**Electric Wind AC Generator Powering an AC Submersible Pump**

The USDA-ARS at the Conservation and Production Research Laboratory, Bushland, TX, is investigating the coupling of an ac submersible centrifugal pump directly to an ac wind generator to operate as a stand-alone water pumping system. Laboratory tests show the system to be very promising. The advantages would be lower initial cost and reduced maintenance. The reason for the potential for lower initial cost is that electric wind generators are lighter, smaller, and made with fewer parts than the multiblade farm-type windmills (conventional windmills). The reason the two- or three-blade wind turbine can be made smaller is it operates at higher efficiency than a multiblade farm-type windmill (about 30 percent for the multiblade, and 40 to 45 percent for the two- or three-blade wind turbine).

Also, the pump system used with the wind turbine may be able to extract more power from the wind turbine than the pump system used with the multiblade windmill. The system should require less maintenance because of the use of a down hole, submersible pump in place of conventional pump rods and well cylinder. Components to assemble an electric wind generator driving an ac submersible pump are commercially available; however, methodology for matching components is not understood or available.

Rotor speed of an electric wind generator is generally proportional to windspeed and is also affected by rotor power loading. Therefore, ac frequency is generally proportional to windspeed and is also affected by power loading. Ac frequency is directly proportional and determines motor rpm. A centrifugal pump pressure is a direct function of rpm squared. When pumping from a well with a centrifugal pump, head or pressure is almost constant. This means that the pump must be run at some minimum rpm just to get the water to the top of the well. Also, there is a maximum rpm that the pump and pump motor can be run at due to motor construction. The result is a window of rpm at which the system can operate and pump water. Depending on components, this window may be only the upper 30 percent of the maximum windspeed the system is designed to operate in. This would mean that a system designed to start operating at 10 mph would not extract additional power from winds above 14.3 mph.

If proper controls were placed on the system, the system could operate in winds above 14.3 mph but would not extract any additional power from these high winds. The Conservation and Production Research Laboratory is conducting tests the staff hopes will lead to a methodology for determining economical matching and operation of ac wind generators driving ac submersible pumps.

**Electric Wind DC Generator Powering a DC Submersible Pump**

The dc centrifugal submersible pumps recently introduced for use with photovoltaic panels can also be powered directly as a stand-alone water pumping system by a dc wind generator. As with an ac wind generator powering an ac submersible pump, the dc wind generator powering a dc submersible pump may be able to extract more power from the wind turbine than the pump system used with the multiblade windmill. Also, the system may be lower in initial cost and should require less maintenance because of the use of a down hole submersible pump in place of conventional pump rods and a well cylinder.

Components to assemble a dc electric wind generator driving a dc submersible pump are commercially available; however, methodology for matching components is not understood, or available.

**Windmill-Driven Air Compressor Operating an Air Lift Pump**

When a windmill-driven air compressor operates an air lift pump, the air compressor is driven directly by the windmill. A hose carries the compressed air to the "air lift pump." The "air lift pump" is located below the surface of the water at least the same depth as the water is to be lifted. The "air lift pump" is actually just a perforated foot piece attached at the end of the drop pipe into which air is discharged. As air is discharged into the foot piece, the water column becomes less dense and is forced up by the denser water on the outside of the drop pipe.

Windmill-driven air compressors operating an air lift pump are produced by the following:

Bowjon
2827 Burton Ave.
Burbank, CA 91504
(213) 846-2620

Massey Enterprises
P.O. Box 1299
R.R. 1, Springpoint Rd.
Fort MacLeod, AB
Canada T0L 0Z0
(403) 553-3552

**Long-Life Well Cylinder**

One problem with conventional windmill operations is the failure of the leathers in the pump cylinder. Life of the leathers has been reported to be as short as 1 day, and as long as 10 years, with a usual life of 6 months to 2 years. When a windmill stops pumping and the pump is in water, the failure of the leathers is generally the problem. They have to be replaced by pulling the rods and traveling valve in an open top cylinder or the rods and drop pipe in a closed top cylinder.

Longer life cylinders are available that extend the time between cylinder pump service a reported five to six times. These pumps have closely fitting, long plungers in a steel barrel. This is the type of pump used in oil wells. These long-life cylinders are available in two designs: rod pump and tubing pump. The rod pump is designed so it can be installed and removed from the well as a complete unit, including barrel, without pulling the drop pipe. The rod pump is attached to the rod end, run into the well, and anchored at the bottom of the well by a seating nipple attached to the drop pipe. Original installations require the pulling of the drop pipe to attach the seating nipple.

In the tubing-type pump, the cylinder barrel with the lower valve is attached to the bottom of the drop pipe and the drop pipe run in. The plunger and traveling valve are attached to the rod end and run in. The lower valve can be pulled with the plunger and traveling valve by letting the plunger down onto the lower valve, screwing the bottom of the plunger onto the lower valve, and pulling the rods. To recover the cylinder barrel, the drop pipe must be pulled.

One disadvantage of the long-life well cylinders is initial cost. The cost is three to seven times the cost of conventional well cylinders.

Long-life well cylinders are available from:

Dover Corp./Norris Division
P.O. Box 2070
Tulsa, OK 74101
(918) 584-4241

Harbison-Fisher
P.O. Box 2477
Fort Worth, TX 76113
(817) 297-2211

**Performance Modeling and Testing of Windmills**

Despite the fact that the water pumping windmill has been in production and operated for over 125 years, performance modeling and testing of windmills is being carried out with new information. Work includes:

1. Evaluation of small-scale wind turbines, Alberta, Canada.
2. Windmill performance modeling by VITA (Volunteers in Technical Assistance).
3. Performance testing of horizontal axis wind turbines for the direct drive of water pumps by the University of Calgary, Calgary, Alberta.
4. Well simulator developed by Wind Baron Corp.

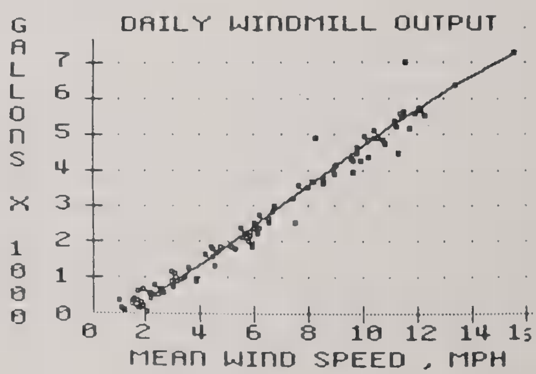
*Evaluation of Small-Scale Wind Turbines.* The Alberta Research Council, Edmonton, is coordinating sponsors of a study to evaluate and demonstrate the potential of utilizing existing wind turbines to efficiently and economically pump water under Alberta's climatic conditions. A budget of $375,000 has been provided for this 3-year study.

Six wind turbines were chosen for test. They are:

1. Dempster 14-ft multiblade with piston pump.
2. Wind Barron 21-ft multiblade with piston pump.
3. Bowjon 8-ft, six-blade with air lift pump.
4. Windcharger 14-ft, two-blade with electric pump.
5. Wilks-cam 12-ft multiblade with piston pump.
6. Maverick 12-ft, three-blade with air lift pump..

Testing is planned to be completed in March 1985.

*Windmill Performance Modeling by VITA.* VITA is developing computer programs that will predict the performance of water-pumping windmills. By knowing the mean windspeed for the day, and the characteristics of the windmill and site, the programs will predict the windmill output for the day.




The VITA computer program produced the curve to predict the water output of a 14-foot Dempster windmill with a 17-meter head, a 3-inch pump, and a 10-inch stroke. The dots are actual performance data recorded in Gravel Bay, Honduras, with a windmill operating at these specifications.

VITA is also developing a life-cycle cost computer model program to calculate the cost of each cubic meter of water pumped over the life of the windmill. Inputs for the program include windmill life, total initial capital investment, operating and maintenance costs, daily water output (obtained from the computer program which predicts performance of water-pumping windmills), salvage value, discount rate, and length of project.

*Performance Testing of Horizontal Axis Wind Turbines for Direct Drive of Water Pumps.* The University of Calgary is conducting performance testing of wind-turbine wheels used on water-pumping windmills. A number of reports have been issued. This work is under the direction of Professor J.A.C. Kentfield, Department of Mechanical Engineering. In one of his tests, he duplicated a wheel used by Thomas Perry (of the Perry Wheel) in his 1883 windmill wheel tests. Professor Kentfield's test results, using modern windtunnel equipment and instrumentation, were the same as Perry's using an open room; a powered, revolving horizontal arm; a pony brake, and strings. Perry's accurate tests, confirmed 100-years later (to the year) by Kentfield, must be considered an extraordinary engineering feat. Perry's work was done for the United States Wind Engine and Pump Co. Batavia, IL, which declined to use Perry's results. So in 1888 Perry (with LaVerne Noyes) formed the Aermotor Co. and began manufacturing his scientifically designed steel windmill wheel known as the Perry wheel. Almost all multiblade water-pumping windmills seen in operation today use the Perry wheel.

*Well Simulator Developed by Wind Baron.* Wind Baron Corp. Phoenix, AZ, has developed a well simulator that can be attached to the bottom of the windmill tower. This simulator can be used to test the windmill performance at any simulated well depth without the need for a well. When using this well simulator, pump-rod weight is simulated by placing weights on a mounting rack attached to the pump pole or red rod. A standard pump cylinder forces water through an adjustable pressure-relief valve during the upstroke, simulating water load or depth. By adding weights and adjusting the pressure-relief valve, any reasonable well depth can be simulated.

**Photovoltaic-Powered Water-Pumping Systems**

In past VREW reports (36th and 37th), photovoltaic-powered water-pumping systems have been reported on in detail. Following is an update:

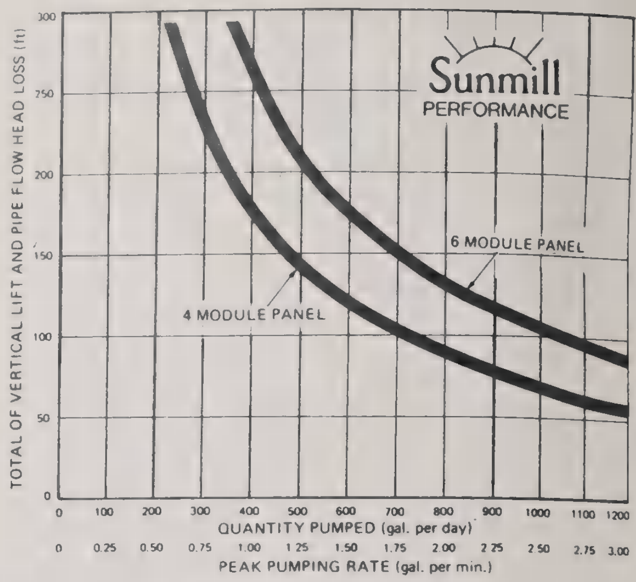
*World Bank Report on Testing Photovoltaic-Powered Water-Pumping Systems.* Sir William Halcrow and Partners, in association with Intermediate Technology Power, Ltd., of London, Swindon and Reading, United Kingdom, under contract to the World Bank, Washington, DC, have produced a report, *Small-Scale Solar-Powered Pumping Systems: The Technology, Its Economics, and Advancement*. This good, detailed report covers the testing and evaluation of 12 photovoltaic-powered water-pumping systems, four of which would have application to range water pumping. Two of the four are U.S.-produced pumps and a third is available in the U.S. Pumps were respectively from the William Lamb Co., Trisolar Corp., and Grundfos. See performance table below.

**Performance Table**

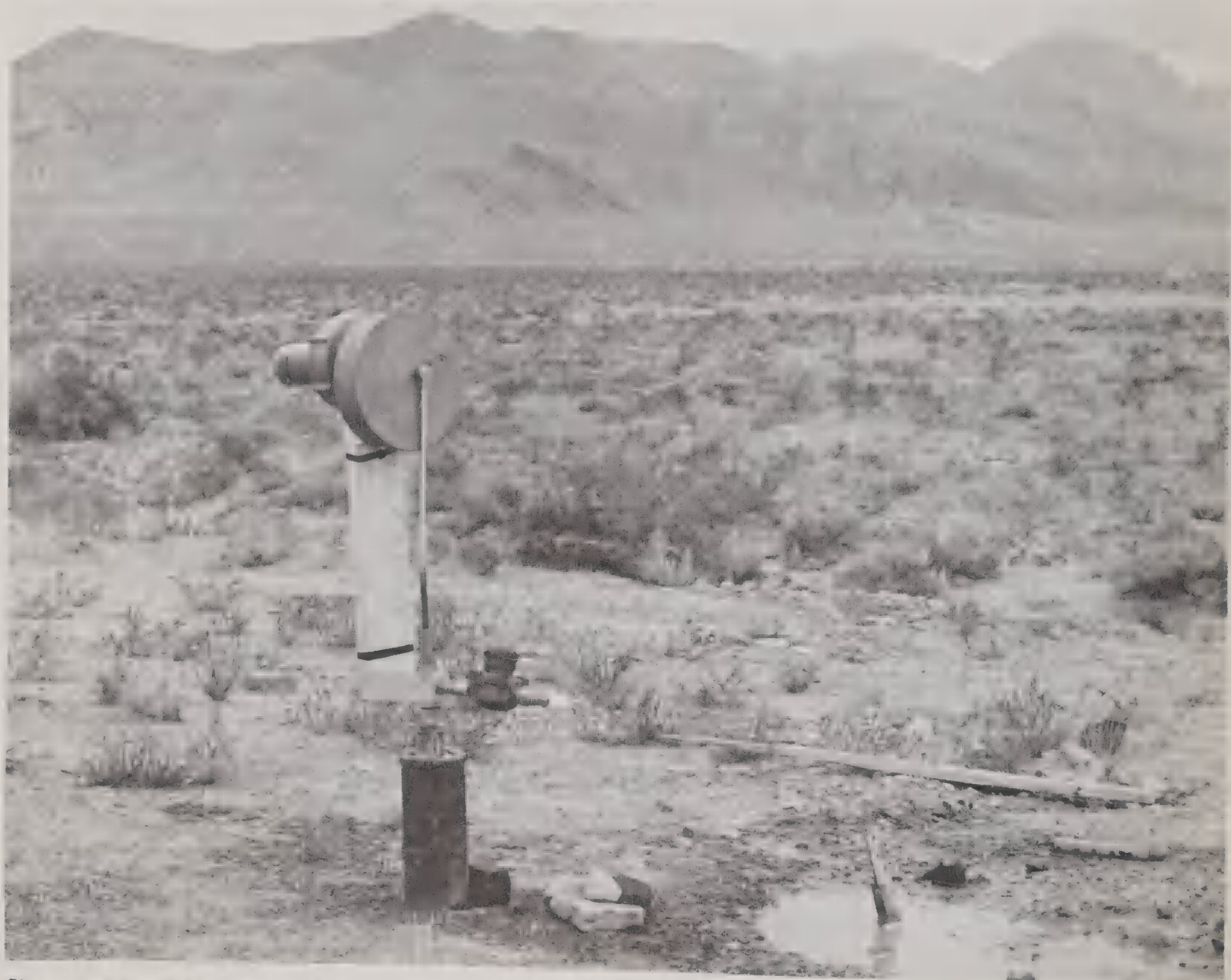
| | Capital cost ($) | Pumping rate (gal/day)[1] | Daily overall efficiency (%) | Maximum wire to water efficiency | Projected specific capital cost ($/gal/day)[1] |
|---|---|---|---|---|---|
| William Lamb Co. | 4,445 | 4,227 | 2.5 | 41 | 1.05 |
| Trisolar Corp. | 10,770 | 5,019 | 2.3 | 38 | 2.15 |
| Grundfos | 7,812 | 8,718 | 3.8 | 44 | .90 |

[1]At 65.6 ft or 20 m. From World Bank report (units changed from metric to English).

*Operation of Series-Parallel Photovoltaic Panel Switching.* The Carson City District of the Bureau of Land Management (BLM), Carson City, NV, with the assistance of the San Dimas Equipment Development Center, installed a photovoltaic-powered water pump with series-parallel photovoltaic panel switching. The pump is performing as specified by the manufacturer (see performance chart). The unit installed was a four-module panel unit. In a series-parallel photovoltaic panel switching system, panels are divided into two equal sets. Within each set, the panels are connected in series and each set is connected to a switching unit that will either connect the two series-wired sets of panels in parallel for combined amperage output, or in series for combined voltage output. During time of low solar radiation, such as early morning or during cloud cover, the switching unit will connect the sets of panels in parallel, resulting in a high amperage and low voltage output that will start or keep the motor running, but at half speed. The unit is manufactured by GPL Industries, P.O. Box 306, La Canada, CA 91011, (213) 790-0762.




Performance chart for series-parallel photovoltaic panel switching pump installed by Carson City District, BLM (four-module panel used).



Photovoltaic-powered pumping unit installed by Carson City District, BLM, using series-parallel panel switching.

*Predicting Counterbalance Weight Required When Using Volumetric-Type Jack Pumps.* When designing and installing photovoltaic water pumping systems using volumetric-type "jack" pumps, it is very desirable to have the electric motor do half the work on the upstroke and half on the downstroke. This is made possible by placing weight (counterweights) on the end of the walking beam so that when the single-acting pump is pumping on the upstroke, counterweights are being lowered supplying approximately half of the work to pump the water. To determine if the counterweight is correct, attach an ammeter to the electric motor driving the pump. If the upstroke amperage is equal to the downstroke amperage, the counterbalance weight is correct. If the amperages of the upstroke and downstroke are not equal, the counterweights can be adjusted by adding or removing weights until the upstroke and downstroke amperage is equal.

Counterbalancing a photovoltaic-powered water pumping system can be very important. Proper counterbalancing can reduce the starting torque of a "jack" pump by up to two-thirds or more. This is important, as torque of a dc electric motor is approximately proportional to current or amperage. In a photovoltaic-powered pumping system without batteries, keeping the amperage as low and steady as possible is important.

The following items have an effect on the counterbalance:

1. Depth of well.
2. Pump cylinder area.
3. Pump rod and moving parts of cylinder weight when in water.
4. Volumetric efficiency of pump cylinder (Veff).
5. Mechanical (force) efficiency of pump cylinder (Feff).
6. Overall efficiency of pump cylinder (Oeff). Note: Overall efficiency = Volumetric efficiency x Mechanical efficiency.
7. Distance from fulcrum of walking beam to center of gravity of counterbalance weights.
8. Distance from fulcrum of walking beam to center line of pump rod.
9. Percent of time for the upstroke and downstroke.

The theoretical counterbalance weight (not considering efficiencies) is one-half the water load plus all the rod load or:

$$TC = \frac{(CA)\ (Lift)\ (.433)}{2} + RW$$

Where

TC = Theoretical counterbalance (rod weight included)

CA = Cylinder area (in$^2$)

Lift = Water lift in feet

.433 = Change pressure from ft head to psi.

RW = Rod and moving parts of the cylinder weight (in water) (lb)

The actual counterbalance required is the counterbalance weight required when considering efficiencies and walking beam length, and is equal to:

$$AC = \frac{(.433)\ (CA)\ (Lift)\ (DS\%)\ Veff\ x}{Oeff\ y} + \frac{x}{y}\ RW$$

Where

AC = Actual counterbalance required (rod weight considered)

DS% = Downstroke percent of time

Veff = Volumetric efficiency (about 90 percent)

Oeff = Overall efficiency of cylinder (about 60-65 percent)

x = Distance from fulcrum of walking beam to pump rod centerline (in)

y = Distance from fulcrum to walking beam to center of gravity of counterbalance weights (in).

The volumetric efficiency can be determined by tests (counting strokes and measuring volume pumped). For a well cylinder pump, the volumetric efficiency has been found to be about 90 percent. If an installation is made and the correct counterbalance weight is found by making upstroke and downstroke amperage equal, the overall efficiency of the well cylinder can be determined. Overall efficiency of one well cylinder operating at 110 ft has been found to be 58 percent by strain gaging the polish rod. (This test validated determining overall efficiency and mechanical efficiency by counterbalancing.) The overall efficiency of a well cylinder may vary considerably over depth and with manufacturer.

If the overall efficiency of a well cylinder is known, the actual counterbalance weight required can be predicted. The benefits of being able to predict the correct counterbalance weight are: The correct size of pump jack unit can be selected and ordered, the correct number and size of counterweights can be ordered, and if the counterweight needed is not the counterweight predicted, there is probably a problem.

## Solar-Powered Pumping Systems

By Mike Easterly, Grundfos Pumps Corp., St. Louis, MO

Photovoltaics, the science of converting sunlight into electrical voltage, has been used for many years. The popularity of photovoltaics blossomed with their use to power radio transmitters on the Vanguard 1 satellite in 1958. Since then, photovoltaic technology has rapidly advanced, and now photovoltaics have become an excellent source for microwave relay stations in telecommunications as well as for corrosion prevention of pipelines and bridges.

Photovoltaics are taking an active role in groundwater pumping with complete solar-powered pumping systems now available. This new approach to pumping offers an innovative energy-saving alternative for many applications.

**Advantages of Solar-Powered Pumping**

Photovoltaics for water pumping have many advantages. First of all, a natural relationship exists between the seasonal availability of sunlight and the water requirement. For example, during the summer when the Sun shines brightest the water requirement of plants and livestock is greatest. It is also during this period that the photovoltaic cells are producing the greatest amount of electricity, and the pumping system is delivering maximum water; as water can be pumped and stored, this water reserve is then available at night and during cloudy periods. The use of overhead tanks, canals, and reservoirs for water storage entirely eliminates the need for storage batteries. The use of such batteries typically results in a 20-percent drop in system efficiency.

Solar-powered pumping systems are ideally suited for remote applications where power utility lines are not available. In addition, solar-powered pumps offer an alternative to the often used diesel-powered generators that require refueling and servicing.

Solar-powered pumping also provides an energy alternative to existing installations using conventional power sources. Because this energy from the Sun is free and virtually limitless, the system is not effected by escalating utility rates, embargoes, black-outs, or power quotas. Furthermore, solar power does not deplete our finite sources of coal and oil, nor does it pollute the environment.

Unlike most conventional pumping systems, which must face large and uncontrollable power utility costs to operate the system, nearly all the expense of the solar-powered pumping system is in the initial purchase and installation. The most costly component of the solar panel is comprised of individual solar cells. The production costs of these cells have fallen from $30 per watt in 1975 to less than $10 per watt in 1982. With further technological advancements on the horizon, the cost of solar panels will continue to decline.

To make a fair comparison between the cost of conventional and solar-powered pumping systems, both initial and operating costs over the life of the systems must be evaluated. The life of the solar-powered system is determined by the solar cell, which has an optimum cell life efficiency of at least 20 years. By comparing the initial cost to purchase and install a solar-powered pumping system to the operating costs of a conventional pumping system over 20 years, the economical feasibility of the solar-powered pumping system becomes apparent.

**System Components**

There are many ways to couple solar panels to pumping systems. Since the panels produce direct current (dc), the system lends itself to powering dc motors. Other approaches include utilizing brushless dc motors and converting to alternating current (ac) systems.

After considering system efficiencies, reliability, ease of installation, and maintenance-free operation, Grunfos selected a dc/ac system. While historically dc/ac inverters have been inefficient, Grundfos designed its own inverter, which operates at efficiencies greater than 96 percent.

The Grundfos system consists of a few simple units—namely, the solar panels, main disconnect switch, dc/ac inverter, and submersible pump and motor. The energy received from the Sun is converted by the solar panels into dc power. This power is fed through a main switch to the dc/ac inverter then converts the dc power into three-phase ac power which is transmitted to a standard submersible motor. The three-phase motor is attached to a submersible pump and installed in the well in the same manner as standard submersible pumps and motors.

Because the ac output voltage and frequency vary with the Sun's change in radiation, the construction of the inverter is unique, utilizing the total power generated by the panels at all times. No storage batteries are necessary. Instead, the water can be stored in a reservoir or storage tank.

The Grundfos solar-powered pumping systems have been tested by one of the world's biggest consulting engineering firms: Sir William Halcrow and Partners in London. The World Bank asked this firm to test promising solar-powered water supply systems on the world market. This task has been carried out during this last year.

A report published by the World Bank, which includes the test results, gives no direct conclusion as to which product is the best. However, it is quite evident from the report that the Grundfos system is superior to all other solar-powered systems.

The test results show that the Grundfos system has the highest hydraulic output in relation to admission of solar energy and that the price of the Grundfos system (dollars per gallon of water) is the most favorable price.

**Sizing a Solar-Powered Pumping System**

The primary differences in a solar pumping system are the factors critical for correctly sizing and selecting the system. Because the system's capacity is regulated by the amount of available sunlight, gallons per minute and horsepower are not primary considerations. Rather, the required gallons per day, the amount of sunlight available throughout the year, and the feet of pumping head become the prime parameters for system selection.

The pumping rate is directly related to the radiation received from the Sun. As the Sun rises in the morning, the pump starts automatically and begins pumping at a low rate. The rate increases, peaks at midday, and then decreases until sunset.

Determining the amount of radiation (sunlight) throughout a year is a more complex calculation. Variables such as geographical location (latitude), the yearly positions of the Earth to the Sun (season), and the rotation of the Earth about its axis (day and night), and climatic and atmospheric conditions (the weather) all effect the amount of daily energy received from the Sun.

During the last 30 years, countries around the world have been tracking and recording such radiation data. Grundfos has gathered this data and with the help of a complex computer program has calculated the effect of different tilt angles on the amount of sunlight available each month at any location in the world. The tilt angle of the solar panel will significantly increase the amount of sunlight which strikes the panel and, consequently, will increase the power produced. During the fall and spring, the Sun creates an angle above the horizon which is approximately equal to the latitude of the location. During the summer and winter, this angle will be higher or lower respectively. These tilt angles, then, play an important factor in the power produced. If one desires the optimum yearly performance without changing the tilt angle, then the latitude of the site should be used for tilt angle. If additional power is wanted in the summer, a decrease in the angle is required. Conversely, if an increase is wanted in the winter, an increase in the angle is required.

Using this data, Grundfos has created a comprehensive design manual which takes into account various tilt angles and permits quick and simple selection of any 22 standard solar pumping systems.

Site selection for the photovoltaic system requires a location that allows the Sun to hit the solar panels during the whole day. In the Northern Hemisphere, the panels should point true south. A deviation of up to 10 degrees to the east or west will not significantly affect the utilization of the energy. However, trees, buildings, and other obstacles in the immediate area that may cast shadows must be taken into consideration. While it is possible to calculate the effects of these obstacles with the use of a Sun chart, the simplest solution is to place the panels in an open space far from trees and buildings. This solution is offset by the requirements to place panels as close as possible to the pumping site since the cable losses also have an effect on the system. In addition, the panels will require a foundation to provide support against winds and other environmental factors.

In conclusion, solar-powered pumping systems are a viable alternative to conventional pumping systems. While the sizing, selection, and installation of these systems are different from conventional systems, the pertinent data and complex calculations have already been compiled and are now available in an easy-to-use selection and installation manual.

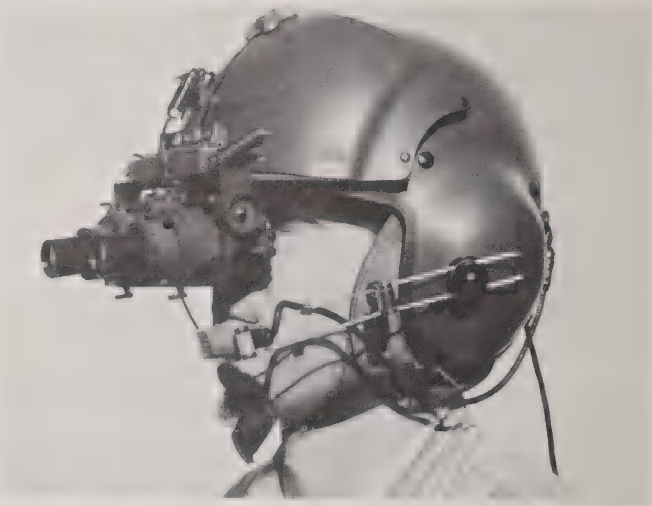
# Forest Service Equipment Development Center Activities

Dan McKenzie from the Forest Service Equipment Development Center at San Dimas, CA, presented a program on current activities of interest not reported elsewhere during the workshop.

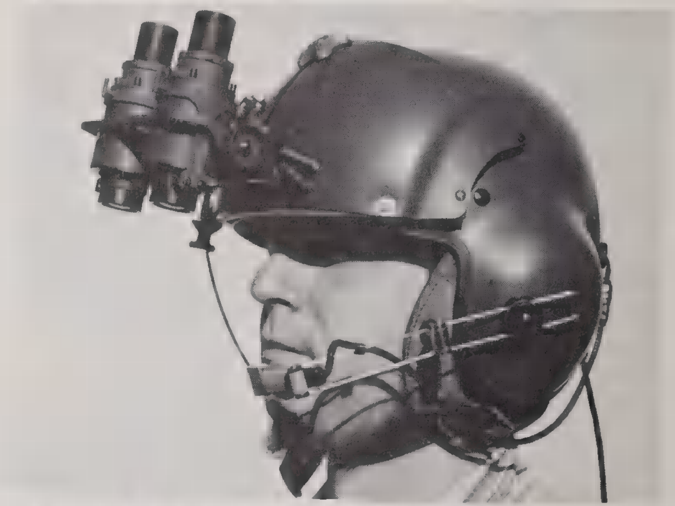
**Helicopter Accessories**
Helicopters play an important part in fire suppression work. For efficient and safe use of helicopters in fire suppression and other duties, they must be equipped with additional accessories, some of which require special design and adaptation. Some of these accessories are:

1. Rapelling hardware.
2. Long lead remote hook systems.
3. Four-hook cargo systems.
4. New lighter-weight night-flying visual goggles.

Work is continuing on all of these items.

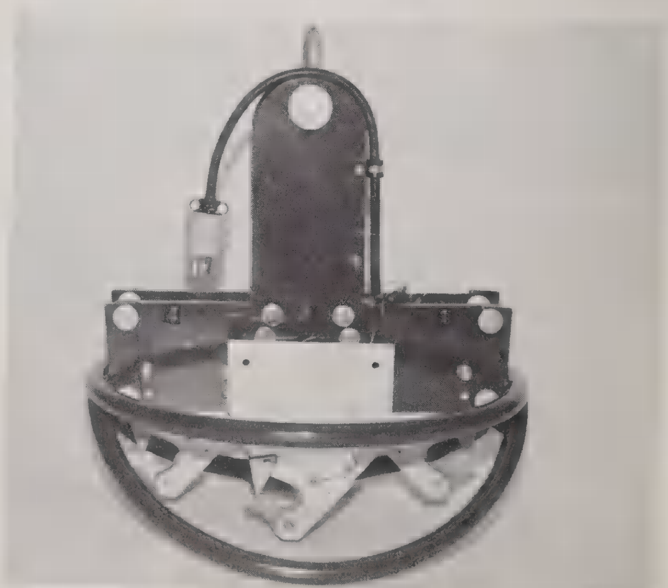


New lighter-weight night flying goggles in viewing position.



Night flying goggles moved out of viewing position.

Helicopter operating with long leadline.



Helicopter multiple-hook carousel for making four separate cargo drops.

**Evaluation of Central Tire Inflation**

The Forest Service oversees the construction of about 10,000 miles of roads each year and the maintenance of approximately 320,000 miles. Much of the cost incurred in road construction is necessary to provide an adequate structure to support logging trucks that currently operate with tire pressures of 70 to 90 psi. Surfacing and structural designs used for aggregate and asphalt surface roads are based on tire pressures of this level. The Forest Service is interested in reducing overall transportation costs of forest products from the stump to the mill of which the road is currently a large part.

Recent developments in tire design and new on-board Central Tire Inflation (CTI) systems have introduced a new element in the existing truck-tire-road system. Tire deflection of 40 to 50 percent of the section height and pressure ranges from 10 to 70 psi are now possible. On a CTI-equipped truck, tire pressure is controlled from the vehicle dashboard.

With low tire pressures, the subsurface structure required can be reduced, resulting in marked cost reductions in road construction. Also, damage to the road by trucks will be reduced or eliminated as results from research show that tires with reduced pressure tend to cause road "healing" rather than road destruction. With CTI systems, it is now possible to attack the vehicular road damage problem at its source.

This project provides for feasibility study and preliminary validation testing of CTI. If this preliminary work shows promise, a long-range analysis and full-scale development project will be required to quantify benefits, identify required policy, design, and contract changes, and to insure adequate CTI systems are developed.

**Gooseneck and Pole Trailer Stability Study**

The objective of this study is to conduct an engineering analysis to support guidelines for selecting truck/trailer combinations that result in safe, economical operation.

This study is the result of requirements to maximize efficiency and maintain or improve safety standards. Since modern fuel efficient trucks are smaller and lighter than previous equipment, there is less margin for allowing unstable or marginally stable truck/trailer combinations to operate.

The results of the analysis will provide the Forest Service a set of critical static and dynamic parameters, and a recommended truck/trailer combination selection methodology. When applied, this methodology, along with vehicle structural, load rating, suspension, drive train, and braking limitations, will identify critical parameters resulting in the selection of safe, reliable, and economical truck/trailer combinations.

Gooseneck trailer.

**Minibackhoes**

In addition to the small backhoe that was reported last year, the Center has also become aware of another unit. These small backhoes can be towed behind a pickup truck and easily handled and operated by one person. The advantages of the small backhoes are that they are low cost, economical to operate, and are able to do small jobs that are too large to be done by hand. Small, minibackhoes that can be towed behind a pickup truck or car are available from:

Walker-Dee Co.
115 South Topanga Canyon Blvd.
Topanga, CA 90290
(213) 455-3044

Swanson Engineering, Inc.
P.O. Box 508
Cedar Falls, IA 50613
(319) 987-2456


The Hopper Hoe (Walker-Dee Co.) can be towed behind a small pickup truck or car.

Mini-Hoe 600 (Swanson Engineering) in operation.

Mini-Hoe 600 can also be towed behind a small pickup or car.

## Slash Treatment Equipment

Many National Forests have slash residue left in the forest as a result of precommercial thinning, partial cuts, and clearcut logging operations. Most approaches to recovering the normal slash and marginal merchantable material are uneconomical due to the number of pieces, with a contributing factor of the steep slope locations of much of this material. For these reasons, slash disposal and treatment is usually quite difficult. The San Dimas Equipment Development Center is working on some equipment that may aid in the utilization and treatment of slash material to reduce its fire hazard. When this equipment is combined into a system, it may offer a potential for slash treatment. One of the first items that may offer some help is a piece of equipment called a Burton Brush Bundler that aids handcrews in making bundles of slash when working on steep slopes.

After bundles are made, they can be moved to a skyline-logging corridor by the use of a tool that SDEDC has developed called a concentrator. Three prototype production models of the concentrator have been fabricated and were field tested in the summer of 1983. The power trains of the prototype production model concentrators are:

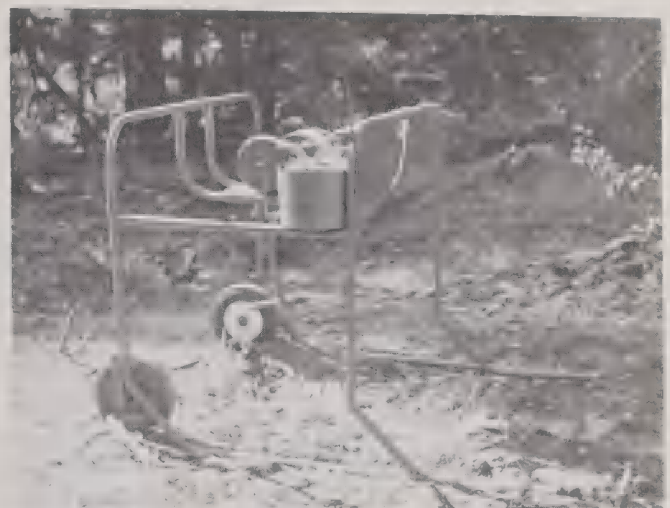
1. An 11-hp engine with a hydrostatic transmission and a 18:1 winch gear ratio.

2. An 11-hp engine with a planetary gear transmission and and a 18:1 winch gear ratio.

3. An 8-hp engine with a planetary gear transmission and a 36:1 winch gear ratio.

All three units performed well, and all three drive train arrangements are acceptable for a production unit.

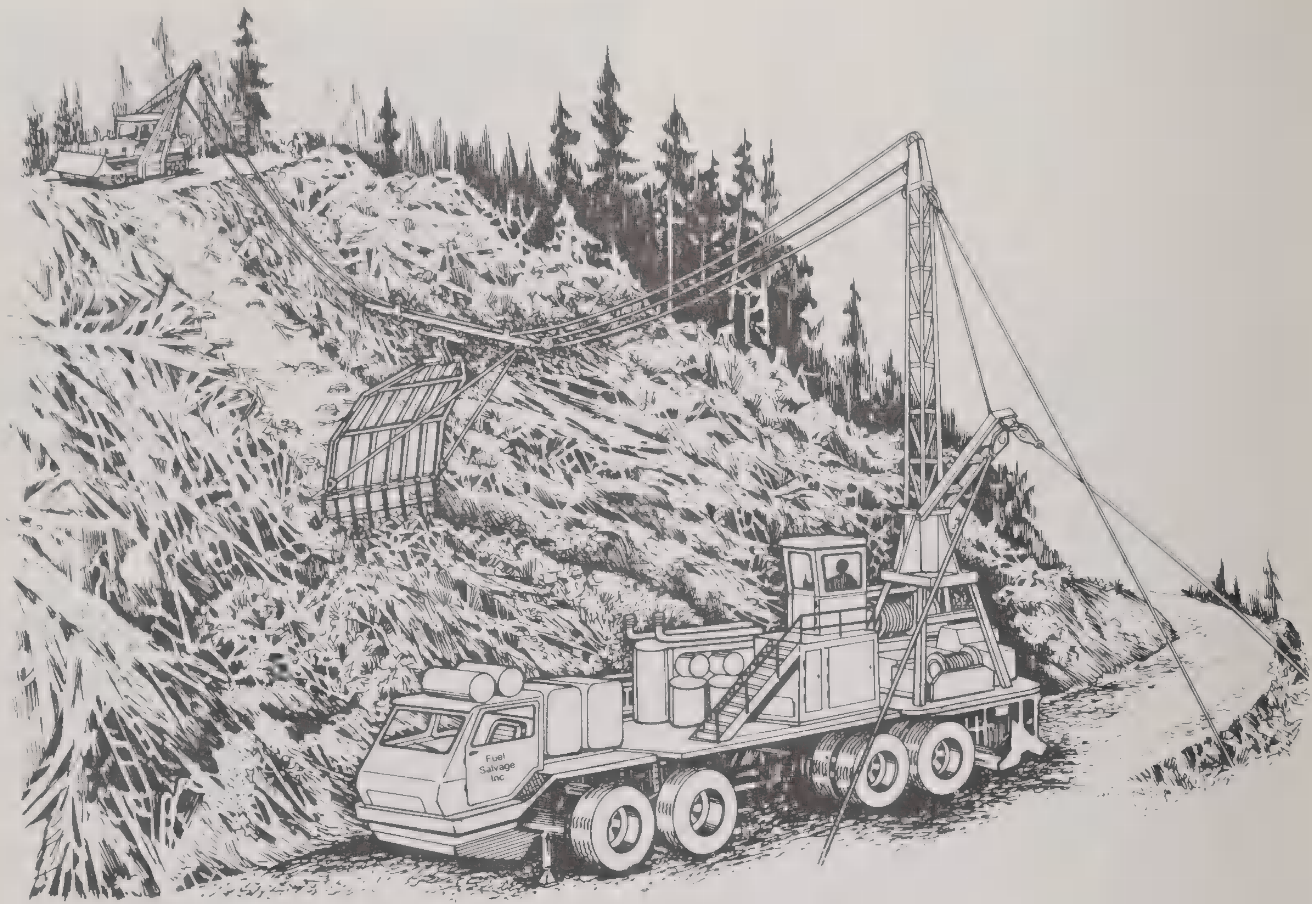
After slash bundles are moved to the skyline-logging corridor with the concentrators, they can be removed by a small, three-drum cable yarder equipped with a slash grapple. Tests to evaluate moving the bundled slash out of the corridor onto a landing have been conducted. Also, using a cable-yarding system, tests were conducted on directly raking the slash area with a special slash rake carried by the cable yarder. A problem may exist with the rake hanging up on stumps and losing its load of slash and residues. Reports are being prepared on this equipment.



Burton Brush Bundler used to aid handcrews in treating slash.

Slash concentrator in operation.

Slash grapple in operation on a running skyline yarder moving bundled slash to a landing.




Artist's concept of operation of a slash rake attachment for a running skyline yarder.

**Mountain-Climbing Backhoe**

In 1981, the Equipment Development Center purchased a mountain-climbing backhoe called the Menzi Muck, and then ran evaluation tests to demonstrate its capabilities. This machine can move itself into almost any location and can do the work that a standard backhoe of this size is capable of doing. There are three European manufacturers that have their hill-climbing backhoes available for purchase through U.S. representatives:

Menzie Muck (Switzerland)
Climbing Hoe of America, Ltd.
100 Commerce Dr.
Fayetteville (Atlanta), GA 30214
(404) 461-6328

Kaiser Spyder (Liechtenstein)
Industrial and Municipal Engineering
P.O. Box N
Galva, IL 61434
(303) 932-2036

Schaeff-Namco, Inc. (West Germany)
P.O. Box 1917
Sioux City, IA 51102
(712) 944-5111

The mountain-climbing machines are used for excavating, pipeline trenching, road maintenance (culverts, binwalls, bridges, etc.), and digging test pits for determining subsurface materials for use in cost estimating structures and roads. Also, they have been used for construction of wildlife ponds and installing landslide drainage structures, along with site preparation for planting in dense brushfields, slash piling, and thinning and windrowing when equipped with a feller buncher; all in inaccessible, remote mountainous areas.

Menzi Muck in operation.

Kaiser Spyder loading itself on a truck.

Schaeff-Namco walking excavator at work.

**Intermittent Bare-Root Tree Planters**
More uniform, higher quality, and lower cost planting are possible advantages of intermittent tree-planting machines. Also, compared to continuous-furrow tree-planting machines, intermittent tree-planting machines generally cause less ground disturbance (resulting in lower soil erosion potential), can require lower energy inputs, and require less site preparation (resulting in further energy conservation), and provide a more natural regeneration appearance. The Timberland Two-Row HODAG and a Marden Model 200 intermittent-furrow tree-planting machine have been field evaluated and a report is being prepared.


Marden Model 200 with onboard power supply intermittent-furrow tree-planting machine.

Timberland two-row HODAG intermittent-furrow tree planter.

# Invited Speakers

## Progress in Nonstructural Range Improvement in the Northern Great Plains--Future Needs

**F.R. Gartner,** *South Dakota State University, West River Agricultural Research and Extension Center, Rapid City, SD*

### Why Mechanical Range Improvements?

Why should researchers and range livestock producers in the northern Great Plains be interested in mechanical range improvement techniques? After all, range management in this region is less complex than in other areas of North American rangeland in that we don't have widespread problems with weedy or woody plants. Granted, there are some severe local problems with leafy spurge, Canada thistle, and ponderosa pine, but these are insignificant when compared with problem plants in the southern Great Plains and Southwest. Mechanical treatments are popular in the northern Great Plains because they conserve water—a direct benefit to native plants.

A brief review of the extent of the range resources of the northern Great Plains will properly set the stage for this discussion. The region occupies about 300,000 square miles or about 192 million acres—approximately one-tenth of the total land area of the United States, excluding Alaska and Hawaii (USDA 1974). Rangeland in the northern Great Plains occurs primarily in the western three-fourths of North Dakota, South Dakota, and Nebraska, the eastern two-thirds of Montana, and eastern one-half and the eastern one-fourth, respectively, of Wyoming and Colorado.

Droughts are frequent, and precipitation in some areas of the northern Great Plains has been less than 75 percent of "normal" on the average of once in every 5 to 8 years. Native vegetation is best suited to withstand recurring droughts and most landowners and land managers would agree that native range is the best use of the land. However, some of the best, as well as some of the poorest, rangeland has been transformed into cultivated land. Perhaps 20 percent of northern Great Plains rangeland has been plowed in the past one to two decades. Despite the plowout, northern Great Plains ranges produce a sizable percentage (perhaps 40 percent) of the Nation's total animal unit months of grazing (Forest-Range Task Force 1972). Most of those AUM's are on non-Federal lands.

Nonstructural, or mechanical range improvement, methods have been under study by Federal and State researchers for several decades. Landowners and Federal agencies have applied mechanical treatments on thousands of acres in the northern Plains. Various treatments have been imposed on a variety of range sites, most with apparent success. The common denominator helping to assure success of mechanical treatments is the occurrence and wide distribution of western wheatgrass over the northern Great Plains. This rhizomatous species has withstood plowing, prolonged drought, flooding, overgrazing, overseeding, and fire and has survived and dominates many range sites.

### Mechanical Treatment—Past Experience

Mechanical treatment of rangeland is not a recent innovation. Some photographic evidence has been salvaged that indicates rangeland treatment was practiced in the late 1930's and 1940's in western South Dakota.

In 1945, Barnes and Nelson reported effects of various furrow configurations and spacings on shortgrass range in southeastern Wyoming. Studies of pitting were intitiated in 1942 by SCS researchers at the Archer Station near Cheyenne. Vegetative response to furrowing and pitting was marked by an almost immediate increase in western wheatgrass. Grazing capacity was increased by one-third following mechanical treatment of shortgrass range (Barnes 1950).

Newspaper accounts reveal that deep ripping of tight clay soils improved dryland crop production in northeastern Wyoming well in advance of the use of this technique on rangeland. In the late 1950's, several western South Dakota landowners and range technicians noted with interest the regrowth of native vegetation over buried cable lines that linked the first Minuteman missile installations. The most impressive feature was earlier green-up in spring and a longer green-forage season in summer compared with adjacent, undisturbed vegetation. While western wheatgrass was seeded over those trenches, the longer green-forage season was attributed to improved soil moisture conditions.

In southeastern Montana and western South Dakota the Bureau of Land Management gained attention in the 1960's with the Model B contour furrower and ripper. Range sites furrowed included clayey, claypan, and saline upland in the 10- to 14-inch precipitation zone. Forage production increases monitored by South Dakota State University range researchers in Butte County, S.Dak., have verified the benefits. While this practice appeared too costly for private landowners at 1960's land values, forage production increases are still evident nearly 20 years after treatment application.

In the late 1960's a study was initiated in Butte County, S.Dak., by J.T. Nichols and J.R. Johnson of South Dakota State University to compare a conventional lister-type interseeder with a tilther-type[1] implement. The study was continued from 1969 through 1972 by W.W. Thompson and F.R. Gartner. Results were reported at the 1973 annual meering of the Society for Range Management, Boise, Idaho. Both methods of furrow construction, *without* seeding, were more successful than deferment alone for improving range condition (Thompson and Gartner 1973). The success of interseeding alfalfa with these two implements on a clayey range site was dependent on grazing management following mechanical treatments.

[1]"Sidewinder Tilther," FMC Corp.

These were but a few of the examples of early research and application of mechanical range improvements. Next, I would like to briefly review on the screen the implements used in various studies in western South Dakota over the past 20 to 30 years. In addition, I will show some of the furrowing implements designed by landowners in western South Dakota. These innovations, and about 25 years of teaching, research, and observation in eastern Wyoming and western South Dakota, will become the foundation for the "crystal ball" finale of my presentation: the future outlook.

**Some Current Work**

One of my initial research projects involved deep ripping of claypan range sites. These sites are widespread in western South Dakota and also occur in the other northern Plains States. That research was published in 1981 in two articles in the *Journal of Range Management* (vol. 34, no. 2). Results indicated that forage production on the average, was nearly doubled after claypan sites were ripped. More important, the western wheatgrass portion in ripped claypan nearly always significantly increased two or more times over the untreated control.

Some of the deep ripping study sites will be in their 12th post-treatment growing season in 1984, and vegetation improvement is still visually evident. However, some types of claypan respond much sooner and to a greater degree than others.

Chiseling, or shallow ripping, is quite commonly employed in western South Dakota to stimulate western wheatgrass production. Implements have varied from rather lightweight chisels to heavier, deep subsoilers. Like all mechanical treatments, chiseling should be done on the contour. Vegetation response is usually better on "normal" sites, i.e., clayey and silty range sites, than on claypan sites, simply because the latter are difficult to penetrate with lightweight chisels.

The last treatment I would like to describe is furrowing. This has been the most popular mechanical treatment in South Dakota. Contrary to reports from Montana, I have not heard of one head of cattle dying in a furrow in South Dakota. Types of furrowers used have been widely different, and all have been designed and built by landowners. The slides will illustrate the several kinds of furrowers used in western South Dakota. Field trials comparing various mechanical treatments applied in the fall of 1978 at two western South Dakota locations are being monitored for vegetation yields, soil water, and soil chemical changes. Yield responses for 1980 through 1983 (tables 1, 2) indicate potential returns from a variety of mechanical treatments.

Table 1.—*Average oven-dry yields (lb/ac) of total vegetation after fall 1978 treatment of a thin claypan range site, W.K. Ranch, Meade Co., S.Dak.*

| | Treatment | | | | |
|---|---|---|---|---|---|
| | None | Rip[1] | Chisel[2] | Furrow[3] | Rip + Furrow[4] |
| 1980 | 256<br>*10* | 490<br>*15* | 751<br>*5* | 392<br>*13* | 630<br>*8* |
| 1981 | 669<br>*15* | 809<br>*29* | 1295<br>*24* | 807<br>*26* | 1247<br>*27* |
| 1982 | 316<br>*23* | 1072<br>*60* | 1351<br>*48* | 1467<br>*58* | 1720<br>*67* |
| 1983 | 253<br>*16* | 670<br>*43* | 997<br>*44* | 953<br>*62* | 1027<br>*63* |

*Values in italics represent western wheatgrass yields as a percentage of total annual yields.*

[1] Construction ripper; depth about 20 inches on 5-foot centers.

[2] Chisel (subsoiler); depth about 12 inches on 2½- to 3-foot centers.

[3] Sparks furrower; furrows 26 inches wide, 3 to 5 inches deep on 5-foot centers.

[4] Shearer ripper-furrower; furrows 10 to 15 inches wide, 8 to 10 inches deep, on 4-foot centers.

Table 2.—*Average oven-dry yields (lb/ac) of total vegetation following fall 1978 treatment of a thin claypan range site, E.H. Ranch, Meade Co., S.Dak.*

| | Treatment | | | |
|---|---|---|---|---|
| | None | Rip[1] | Furrow[2] | Rip + Furrow[3] |
| 1980 | 449<br>*64* | 660<br>*36* | 662<br>*11* | 663<br>*20* |
| 1981 | 1012<br>*33* | 1230<br>*41* | 2191<br>*15* | 1846<br>*19* |
| 1982 | 1273<br>*39* | 1838<br>*41* | 2588<br>*26* | 2560<br>*39* |
| 1983[4] | 687<br>*41* | 1020<br>*43* | 1408<br>*32* | 1259<br>*50* |

*Values in italics represent western wheatgrass yields as a percentage of total annual yields.*

[1] Construction ripper; depth about 20 inches on 5-foot centers.

[2] Sparks furrower; furrows 26 inches wide, 3 to 5 inches deep on 5-foot centers.

[3] Shearer ripper-furrower; furrows 10 to 15 inches wide, 8 to 10 inches deep, on 4-foot centers.

[4] Forage yields reduced by grazing in June and early July. Western wheatgrass average utilization estimates July 18, 1983, (after cattle were removed), were 6, 7, 9, and 10 percent, respectively, on the control, ripping, furrowing, and rip + furrow treatments. Sweetclover average utilization estimates were 72, 71, 61, and 67 percent, respectively, on the same treatments.

Finally, I'd like to comment on a few implements or treatments that have been tested, but not with consistent success. These include a water-filled drum with disks that punch small furrows into the soil[2] an alfalfa interseeder, and a rototiller or tilther-type of implement (previously mentioned). The first two implements did not appear to be designed for range soils and climate. The tilther-type of implement may be suited for some range sites, but needs further study. Pat Currie will discuss current research in Montana with that type of implement in the next presentation.

**Future Outlook**

The most highly variable and unpredictable factor affecting range forage production, and a ranch operation, is precipitation. Forage production, or the lack of it, also affects range wildlife, range hydrology, and range recreation measured by its esthetic value.

If annual range forage production was graphed over several decades, the annual yield fluctuations would appear similar to those of a graph of annual precipitation over time. Both annual and seasonal precipitation affect forage yields. The most basic interrelationship, it appears, is that of soil moisture and forage yields. If year to year fluctuations in soil moisture could be stabilized, annual forage yields would become more dependable.

A large portion of precipitation in the northern Great Plains is *ineffective* due to the nature of the precipitation and to physical limitations of soils to absorb water. For example, in the 10- to 14-inch precipitation zone, perhaps only 45 percent of annual precipitation is *effective* on a claypan range site; 55 percent may be unavailable for plant growth because it's lost as runoff and evaporation. Thus, many claypan sites in the northern Plains are, in fact, "desertified."

There is an apparent link between effective precipitation, soil characteristics, forage production, and livestock performance. The latter is specifically a function of forage quality and quantity. In over 25 years of examining various range inputs, most of which were spent in the northern Great Plains, mechanical treatments appear to be the most consistent range improvement for assuring the stability of forage quantity and improvement of forage quality. Further, mechanically treated range provides the best "grass insurance" during dry cycles.

The first priority in future range improvement design should be energy efficiency. Implements cannot be so heavy that crawler of four-wheel-drive power is required, unless fuel costs dramatically decrease.

Contour furrowing appears to be most universally successful across a wide variety of range sites, but data are not available as yet to define optimum furrow width, depth, and spacing. An important point for research and extension personnel to remember if they promote furrowing is that there is no need for treating *every* acre on any unit of range. Vehicle and livestock pathways are important. The benefits of furrowing are most profound during drought cycles. Furrowing benefits may be best achieved on winter pasture to reduce feeding requirements and collect snow, especially in late winter. Snow in late winter and spring usually melts quickly, but may often be lost through runoff when the soil is frozen. Furrows retain water and allow it to percolate into the soil profile.

Some claypan sites respond favorably to furrowing. Others require a combination of ripping and furrowing to both fracture the claypan and to accumulate sufficient water to leach salts downward. A classification of various claypans based on soil chemical and physical properties is needed. Productivity of claypan sites in western South Dakota ranges from highest on soils occupied by mid and short grasses with little or no bare ground (slick spots), to lowest soils that support a dwarf form of big sagebrush with abundant cactus and bare areas. Intermediate between these two are soils supporting a good stand of western wheatgrass, some shortgrasses, and silver sagebrush.

Overseeding mechanically treated sites with sweetclover appears to be economically and physically beneficial. Sweetclover provides added forage, its roots open channels through restrictive soil layers, and dormant ungrazed or regrowth sweetclover is a good collector of snowfall in winter. The benefits of nitrogen fixation in the soil are also apparent in associated grasses.

Plant breeders and geneticists should examine specific characteristics of native legumes for potential interseeding in the northern Plains. The infrequently occurring annual, spanish-clover deervetch (*Lotus americanus*), is a prolific seeder, but information is lacking on its nitrogen fixation capabilities and seed characteristics.

Recent greenhouse pot tests indicate possible minor element deficiencies in at least one form of claypan soil. Soil scientists should more closely examine the chemical characteristics and soil water relations of at least those soils occurring on the most common or most abundant range sites in the northern Great Plains. Somewhat related are the effects of city wastewater on range soils. The problems of city wastewater have compounded in recent years. Unless a radically new waste treatment is devised, rangelands may soon become the waste disposal sites of cities throughout the West. If wastewater properties can be absorbed by range soils and vegetation without harmful effects on either, shouldn't range scientists be studying cost-effective means of transporting wastewater to rangeland disposal sites?

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[2] "Rainsaver."

Mechanical treatments can result in large increases of undesirable plant species such as the annual Japanese brome (*Bromus japonicus*). Prescribed burning can be used to successfully reduce density of Japanese brome and, at the same time, stimulate yields of western wheatgrass (Gartner et al 1978). Research combining mechanical treatment and burning has not been conducted to my knowledge.

Range professionals need to closely examine the question of why most ranchers adopt livestock improvement techniques faster than range improvement techniques (Vallentine 1983). One factor related to this question is that of subsidies for mechanical range improvements on private lands and greater allocations for these practices on public lands. More assistance is needed for the private landowner because of the benefits to range uses other than livestock, such as wildlife.

At current prices for rangeland, mechanical treatments that can double forage production offer real promise to the northern Plains range livestock operator. Mechanical improvements appear to be the most viable economic alternative to the purchase of additional rangeland.

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# Range Improvement Machine

**P.O. Currie and R.S. White,** *Agricultural Research Service, Miles City, MT,*
**L.R. Erickson,** *Montana State University, Bozeman, MT*

A prototype rangeland improvement machine (RIM) was developed for interseeding rangeland or renovating problem marginal farmland. The unit tills the soil, forms a vee-trough seedbed and plants in a single-pass operation. Soil tillage is accomplished with a rototiller. A packing wheel assembly forms continuous, packed furrows on farmland. On rangeland, the furrows have intermittent check dams for water retention and control. Furrows are large enough to retain water and remain intact for a number of years but small enough to minimize field traffic problems. Various types and combinations of seed and fertilizer can be planted and applied with the modified all purpose drill.

**Major Performance Features**

1. Soil tillage seedbed preparation, planting, and fertilization for rangeland or marginal farmland improvement can be done in a single-pass operation.

2. Furrows developed by the packing wheel assembly retain water when installed on the contour and provide a desirable microclimate for seed germination and plant growth. They make an effective irrigation row on marginal farmland that is reasonably level.

3. The RIM utilizes commercially available components for the rototiller and drill. The packing unit is custom fabricated. RIM has a 100-inch (254 cm) working width and is constructed to allow any row spacing between 10 and 100 inches (25 and 254 cm) by 10 inches (25 cm) increments per machine pass.

4. The drill has individual hoppers and individually adjustable meters for applying granular fertilizer and any combination of legume, grass, or small grain seeds.

**Machine Components and Design Features**

First and second generation RIM's have received field testing. Design features have been reported previously for the first generation (Erickson and Currie 1982). Figure 1 presents a side view of the current RIM showing its component mechanisms. On both generation machines, the rototiller operates from the PTO of the tractor. A tractor rated at 100 to 150 drawbar horsepower (80 to 120 kW) has been used for the power source. Rototiller tines and packing wheels are selectively added or removed to create tilled strips for the drill unit. The packing wheel frame is mounted directly behind the rototiller and the drill immediately behind the packing unit, which provides good drill tracking in the packing wheel furrows. The main frame has transport wheels that are retracted for field work (fig. 2). A weight box was added to insure sufficient down pressure on the packing wheels. Packing wheels are individually attached to a common axle to allow for row spacing adjustments. A 5-inch-deep (13 cm) vee trench with check dams every 7.6 feet (2.3 m) is formed by each packing wheel during seedbed preparations on rangeland. A removable insert for the wheel notch is put in place so that continuous furrows can be made on irrigated farmland (fig. 3).

A modified commercial drill is attached to the rototiller-packing wheel frame. A "float" position is provided on the hydraulics for the tiller and drill so that the tiller can creep over rocks, and the drill will follow ground contours and not be forced into the soil. All meters on the drill are driven by an end-wheel ground-drive system. Provisions have been made to close off unneeded meters in each hopper on an individual basis. The end wheels are necessary to support the drill, since the opener springs do not provide down pressure. The end wheel is spaced so it can ride in a furrow from the previous pass during full-width tillage on irrigated land. Narrow single-rib tires prevent damage to the furrow. On rangeland with intermittent furrows, this is not a consideration.

Double-disk openers with specially developed depth bands on both sides of the openers control seed placement. The depth bands insure a seeding depth of ½ to ¾ inches (1-2 cm), which

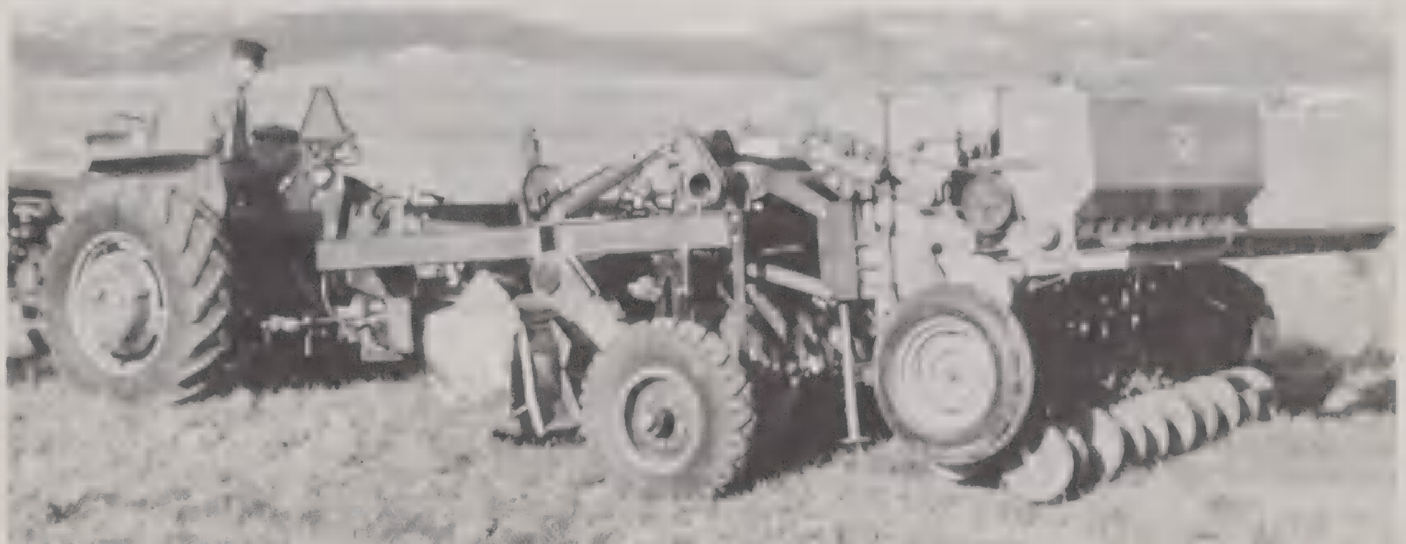

Figure 1.—RIM in transport position showing component configuration.

Figure 2.—Main frame showing hydraulics and lift configurations for tiller, transport wheels, and drill.

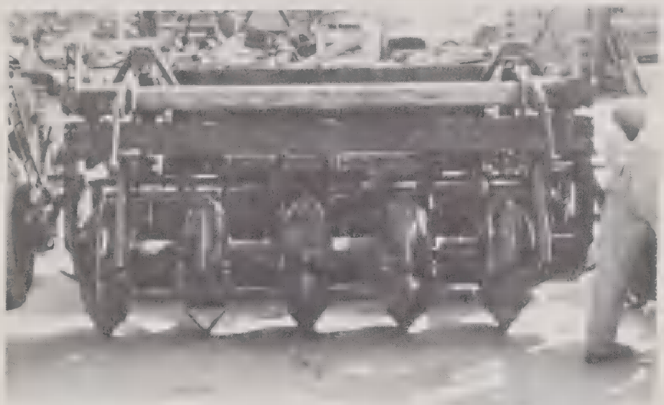

Figure 3.—Packing wheel unit configured for alternate row tillage with "cutouts" removed to form check dams on contour tilled native range.

is essential for good grass stand establishment. Seeds are fed through drop tubes from each of three boxes into the disk openers through a specially developed drop tube manifold that merges the three separate tubes. To prevent destruction of the intermittent check dams, the opener springs are not used on rangeland. Shallower-than-normal seeding depth caused by low down pressure on the openers has not been a problem because some natural erosion in the furrow tends to cover the seed, and a shallow planting depth is usually desired. The openers are followed by standard 2- by 13-inch or 1- by 10-inch (5 by 33 cm or 3 by 25 cm) rubber-tired, seed-packing wheels.

There are four boxes on the drill, and the drive sprocket ratios are changed to vary application rates from each of the boxes. The front box is for granular fertilizer, which is metered independently and top dressed in front of the double disk openers. The second box is for grass seed. This unit uses a picker-wheel metering assembly on which the seeding rate is adjusted by varying the drive sprocket gear ratios. Drop tubes are directly over the double-disk openers to insure uniform grass seed flow, accurate placement and to avoid bridging by light or fluffy seed. The third box is for small seeds or legumes and has a fully adjustable fluted metering system. These seeds are also fed through the double-disk openers. The fourth box is for small grains. Drop tubes from this box travel at a considerable angle to reach the openers. This has not been a problem, since the weight and geometry of small grains seeds insures transit through the tubes.

Rangeland Use:

The RIM was primarily designed for seeding native and introduced species into semiarid rangeland of the northern Great Plains. This type of work would normally be done on the contour with row spacings 20 to 60 inches (50-150 cm) apart, depending on species, land form, or other conditions. Rototiller tines, packing wheels, seeding meters, and drill openers in rows that are not being used are removed or deactivated.

The tractor operator follows previously established contours with the unit, creating a seeded and/or fertilized contour furrow with intermittent check dams. Some operator discretion is required to maintain the machine on contour, and to make layout decisions where contours come together or diverge because of landform or field irregularity.

Farmland Use:

The RIM can be used to establish continuous furrows for irrigation purposes by filling the notch in the packing wheel. For establishing completely new pastureland, all 100 furrows would normally be used, creating a fully tilled field. Opener spring down pressure can be increased if desired, as there are no check dams to preserve.

**RIM Field Trials and Experimental Plot Establishment**

The units developed and described have been effective for renovating semiarid rangeland and marginal pastureland. Modifications are being made as needed to improve machine performance. Test plots established with the first generation machine in 1981 on irrigated saline soils and plots established in 1982 on upland rangeland sites have both been successful. Additional plot work, testing, and evaluation is in progress or was made on some rockier soils in western Montana in 1983 using the second generation machine.

A problem, saline bottomland pasture at the Fort Keogh Livestock and Range Research Laboratory at Miles City, Mont., was treated in September 1981 to evaluate the RIM's potential for reclaiming marginal pastures. The unit was used to till this field on tests for plant establishment at different times of the year. A well-tilled soil with a firm seedbed was accomplished under good moisture conditions. No power train or rototiller clutch-related problems were encountered during stand establishment when soil moisture levels were optimum and averaged 20 to 25 percent. However, the rototiller clutch was overloaded when the full-width unit was worked on this heavy clay sod when moisture was limited and the soil dry. Also, "gumming" of the clay into large balls around the tines occurred if the RIM was used when soils were wet.

Planting in the bottom of the furrow was most beneficial under the existing saline conditions. Soil moisture in furrow bottoms remained high, which improved seed germination and establishment. Also, evaporation tends to be more rapid and occur at the ridge crests between rows, which results in a saline crust frequently being developed at the ridge crests. Furrows established in the gently sloping, unleveled field showed some signs of moderate washing at the lower end of the quarter-mile-long field. However, these individual furrows held up reasonably well for 2 years under irrigation and showed a vee profile with 10 inches (25 cm) between ridge crests and a furrow depth of about 3 to 4 inches (7-10 cm). Excellent grass and grass-legume stands were established from all of the RIM tests made.

On rangeland, the unit was not used until the spring of 1982 because of severe drought conditions at the test sites. Eight blocks of 30 acres (12 ha) each were established at two separate test sites to test seven different treatments and a control. The renovated range sites are typical of many areas in southeastern Montana. They are in poor to fair condition, typified by sagebrush, low-growing cactus, blue gramma grass, and other drought-tolerant species of low forage value. One site is on a well-drained silty clay loam with rolling contours. The other site is on a heavy clay panspot area.

Treatments established included (1) control (no treatment); (2) contour furrowed and seeded to alfalfa and cicer milkvetch; (3) RIM-treated, seeded to the legumes, and chopped or sprayed with herbicide for brush control; (4) Rim-treated and seeded to the legumes; (5) RIM-treated and fertilized; (6) RIM-intertilled and packed only; and (7) & (8) RIM-treated, seeded to legumes, sprayed with herbicide for brush control, and grazed on an alternate season basis. The entire experiment covers approximately 480 acres (190 ha) of rangeland. Again, good to excellent 2-year-old stands of alfalfa and cicer milkvetch have been interseeded and established within native range plant communities.

**Conclusions**

To date, field work has been an effective test of machine concept and machine components. The machine performs according to the initial concept when soil moisture conditions are good. A number of rototiller tines have been worn out, but breakage has generally not been a problem even on the rockier test site in western Montana. A firm vee-shaped seedbed with relatively solid check dams is created by the packing wheels. As the soil moisture level drops, the furrows and check dams become softer. Scrapers are required on the packing wheels and the double-disk drill openers to prevent soil accumulation when soils are moist and ideal for planting. Also, soil bodies build up in the packing wheel notches and must be removed periodically, particularly on moister areas with heavier clay soils.

Mechanical components of the field generation prototype machine were rigorously tested in establishing the research treatments. Several structural components were damaged or failed during field tests and have been modified, strengthened, or replaced in the current RIM. The wear and fatigue problems were attributable to stresses imposed by severe operating conditions.

The present machine weighs approximately 5 tons, and each main component is relatively heavy. The drill weighs about 2,500 pounds (1100 kg) when fully loaded, and is normally lifted to make sharp turns at the ends of the field. The packing wheels and frame weigh more than 1500 pounds (680 kg), and the weight box adds another ton, to the unit. All of these components plus the tiller are raised and supported by the transport wheels during turns and road transport. Modification of some of these items on the second generation machine has alleviated earlier stress problems. Testing will continue with this second generation research machine.

A prospectus has been developed for VREW for a third generation machine suitable for use by individual ranchers, agencies, or conservation districts. This machine would be less complex and of lower cost than the prototype research machines. Construction is contingent upon approval and funding.

**Literature Cited**

Erickson, L.R. and P.O. Currie. 1982. A multifunction rangeland improvement machine for semiarid regions. ASAE paper 82-1021. American Soc. Ag. Engr., St. Joseph, MI 49085.

# Equipment Development and Test Funding

## Planning and Budgeting Procedure

For many years the "Range Reseeding Committee" was an informal group, meeting each year to exchange information on work of mutual interest and to develop project proposals for work to be done by Equipment Development Centers or field units. The proposals were written, estimated for cost, and finalized "on the spot." Informal but it seemed to work!

Today there are demands being placed on us to plan in detail 2 years in advance, and in general 5 to 10 years ahead. This does take away some of the informality of the operation and dictates the need for a more organized approach to the preparation and submittal of project proposals. Figure 1 shows a plan by which we can meet our budgeting dates. It provides a mechanism whereby the Equipment Development Centers can stay with the budget process of the Forest Service.

The other aspect of our planning procedure is a more uniform format for project proposals. Figure 2 is a suggested guideline for proposals. Following this guide will help all concerned in preparing and reviewing proposals. It should make the flow of information more efficient and provide a much better story for those who must analyze needs, prepare programs, and assign priorities.

We hope that everyone associated with the Vegetative Rehabilitation and Equipment Workshop will cooperate in this more formal approach. It should be an aid to everyone. If any questions arise or there is a need for help in this process, call the Centers or the Washington Office.

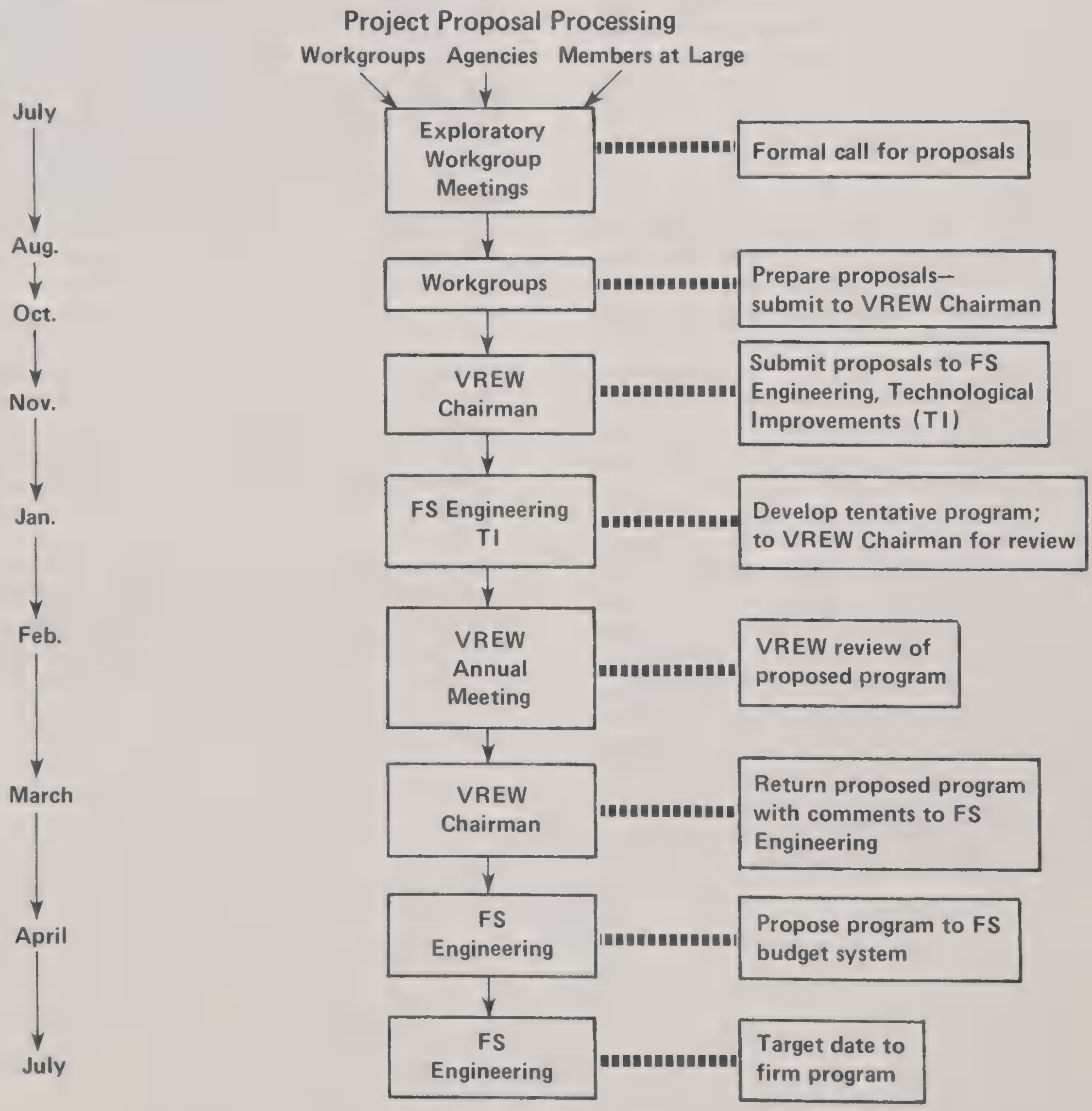


Figure 1.—Project proposal processing.

*(PROJECT PROPOSAL FORMAT)*

EQUIPMENT DEVELOPMENT AND TEST PROJECT PROPOSAL FOR FY ____

ED&T Project No. (Leave Blank)
Date ____________________
Primary Interest: ________

______________________________
*(TITLE)*

- *(The title should be brief and indicative of project objectives.)*

PROBLEM STATEMENT AND OVERALL OBJECTIVES

- *(State the problem and describe how the work is currently being done. Tell what equipment, materials, or methods are used, and why change or improvement is needed. Show significant advantages and potential savings, such as: increased production or efficiency, property or human hazard reduction, reduced maintenance, and public demand or reaction.)*

- *(State the overall objectives. What is to be accomplished or what is to be achieved by this project?)*

- *(Include amendments to the problem statement and overall objectives, if necessary (for completion by the Development Centers for applicable continuing projects only). The statements of the original problem and objectives should not be changed. If there is a change in emphasis, add revised problem statements and objectives here.)*

SPECIFIC REQUIREMENTS

- *(Distinguish between minimum requirements and those which are desired but not essential. Describe features required or specify performance characteristics. Where more information will be needed but cannot be furnished, list items that should be explored.)*

PRIOR DEVELOPMENT

- *(Briefly describe work already completed or underway which is related to this project. On new projects, this work will generally have been done by other persons or organizations or under other equipment development projects. For a continuing project, tell when it started and briefly state major accomplishments, and actions planned for completion in the current fiscal year. Reference the overall project time frame and total cost estimate if previously made and if applicable, prior reports and publications.)*

PROJECT ORIGIN

- *(Show the name, organization, etc. of persons originating the project and preparing the project proposal.)*

Figure 2.—Format for project proposal.

## FY 1984 Program

### Missoula

| | Project | Amount |
|---|---|---|
| TE02D15 | Technical Services, Range | $ 16,200 |
| 7E72D22 | VREW Information Workgroup Support | 20,400 |
| 4E42D30 | Disk Chain Improvements | 50,300 |
| | | **$ 86,900** |

### San Dimas

| | Project | |
|---|---|---|
| TE02D17 | Technical Service, Range | 9,500 |

# Range Publications and Drawings

Below are titles of reports on a variety of range rehabilitation topics, as well as a list of range equipment fabrication drawings. These materials have been produced by the Forest Service Equipment Development Centers at Missoula (MEDC) and San Dimas (SDEDC) and may be of interest to workshop members. Single copies of the reports are available without charge by writing to the appropriate Center. Some drawings are available without cost also; there may be a small charge for others.

Forest Service, USDA
Equipment Development Center
Bldg. 1, Fort Missoula
Missoula, MT 59801

Forest Service, USDA
Equipment Development Center
444 East Bonita Ave.
San Dimas, CA 91773

The list of publications includes *Equip Tips,* concise reports dealing with new equipment, new uses for equipment, and similar topics; *Equipment Development & Test (ED&T) Reports,* documenting major development studies; *Project Records,* describing the technical details of development work, including procedures, results, conclusions, and recommendations; a number of special reports, ASAE papers, and service manuals are listed under "Other Reports."

**Equip Tips**

Bitterroot Miniyarder for Light Forest Materials, May 1983—MEDC

Small Yarder for Steep Terrain, May 1981—MEDC

Resource Publications, Dec. 1980—MEDC

Proper Use of Fusees, Feb. 1980—MEDC

Improved Aerial Ignition System, Jan. 1980—MEDC

Protecting Western Conifer Seedlings, May 1979—MEDC

Steep-Slope Seeder for Roadside Slope Revegetation, Feb. 1979—SDEDC

Improved Method for Joining Plastic Pipe, Dec. 1978—MEDC

Seed Dribblers (revision no. 1), July 1977—SDEDC

Spray Boom Assembly, July 1972—SDEDC

Plastic Pipe Laying Machinery, Jan. 1966—SDEDC

Browse Seeder with 20-inch Scalpers, Jan. 1965—SDEDC

**ED&T Reports**

Catalytic Converter Exhaust System Temperature Tests, Feb. 1977—SDEDC

Slash . . . Equipment and Methods for Treatment and Utilization, April 1975-SDEDC

Clearing, Grubbing, and Disposing of Road Construction Slash, Oct. 1976—SDEDC

Roadside Slope Revegetation, June 1974—SDEDC

Flexible Downdrains, Jan. 1974—SDEDC

Tractor Attachments for Brush, Slash, and Root Removal, Jan. 1971—SDEDC

Results of Field Trials of the Tree Eater, Jan. 1970—SDEDC

Forestland Tree Planter, Sept. 1967—SDEDC

Pine Seed Drill, Sept. 1967—SDEDC

**Project Records**

Preventing Livestock Water from Freezing, Nov. 1983—SDEDC

Rangeland Fencing Systems State-of-the-Art Review, Oct. 1983—SDEDC

Evaluation of the Pettibone Slashmaster Model 900 for Site Preparation in the Lake States, Feb. 1983—SDEDC

Dryland Plug Planter, Dec. 1982—MEDC

Tree-Planting Machine—How Much Can You Afford to Pay for One?, June 1981—SDEDC

Sod Mover Bucket, Dec. 1980—MEDC

Tree/Shrub Planter for Roadside Revegetation, Oct. 1980—SDEDC

Observations on Operations of the Pettibone Hydro-Slasher PM 800, Feb. 1980—SDEDC

Basin Blade for Disturbed Land Revegetation, Nov. 1979—MEDC

Plastic Tubes for Protecting Seedlings from Browsing Wildlife, July 1979—MEDC

Mulching-Tilling Equipment for Soil Conditioning, Jan. 1979—MEDC

Evaluating Methods for Joining Polyethylene Pipe, Dec. 1978—MEDC

A Transplant System for Revegetating Surface Mined Lands, Nov. 1978—MEDC

Grapples for Forest Residues Concentration and Removal, Oct. 1978—SDEDC

Field Equipment for Precommercial Thinning and Slash Treatment, July 1978—SDEDC

Modified Hodder Gouger, Dec. 1977—MEDC

An Investigation of Equipment for Rejuventating Browse, Aug. 1977—MEDC

Survey of High-Production Grass Seed Collectors, Jan. 1977—SDEDC

Remote Sensing for Big Game Counts, Dec. 1976—MEDC

Evaluation of the Vermeer Model TS-44A Tree Spade for Transplanting Trees on Surfaced Mined Land, Feb. 1976—MEDC

Wildlife Habitat Management Needs, Oct. 1975—MEDC

Using Heat for Sagebrush Control, Feb. 1972—MEDC

**Other Reports**

Manual of Revegetation Techniques, May 1984—MEDC

37th Annual Report—Vegetative Rehabilitation and Equipment Workshop, Oct. 1983—MEDC

Development of a Containerized Shrub Injection Planter Attachment for a Backhoe—A Prospectus, Jan. 1983—SDEDC

Dryland Plug Planter—Operator's Manual, Jan. 1983—MEDC

History of the Vegetative Rehabilitation and Equipment Workshop (VREW) 1946-1981, Dec. 1982—MEDC

36th Annual Report—Vegetative Rehabilitation and Equipment Workshop, Sept. 1982—MEDC

Punch Seeder for Arid and Semiarid Rangelands—A Prospectus, Sept. 1982—SDEDC

Development of A Disk-Chain Implement for Seedbed Preparation on Rangeland—A Prospectus, July 1982—SDEDC

Arid Land Seeder Development—A Prospectus, July 1982—SDEDC

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Catalog for Hand Planting Tools, May 1982- MEDC

Sources of Seed and Planting Stock, Oct. 1981—MEDC

Sod Mover Operator's Manual, Feb. 1981—MEDC

Development of a Rangeland Interseeder for Rocky and Brushy Terrain (ASAE paper 80-1552), Dec. 1980—SDEDC

Equipment for Reforestation and Timber Stand Improvement, Oct. 1980—Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402; Request Stock No. 001-001-00563-1; $6.50.

34th Annual Report—Vegetative Rehabilitation and Equipment Workshop, Sept. 1980—MEDC

Modified Basin Blade—Operator's Manual, Mar. 1980—MEDC

Sodder brochure, Mar. 1980—MEDC

Basin Blade brochure, Mar. 1980--MEDC

Mulching-Tilling System brochure, Mar. 1980—MEDC

Transplanting System brochure, Mar. 1980—MEDC

Sprigger brochure, Feb. 1980—MEDC

Dryland Plug Planter brochure, Feb. 1980—MEDC

Revegetation Equipment Catalog, Feb. 1980—MEDC

Agricultural Engineer's Role in Rangeland Improvement and Rehabilitation Equipment (ASAE paper 79-161), Dec. 1979—SDEDC

Observations on Operations of a Residue Shredder and a Brush Harvester, Sept. 1979—SDEDC

33rd Annual Report—Vegetative Rehabilitation and Equipment Workshop, July 1979—MEDC

Front-End Loader Tree Spade--Manual Supplement, Feb. 1979—MEDC

35th Annual Report—Vegetative Rehabilitation and Equipment Workshop, Sept. 1981—MEDC (Available from National Technical Information Service (NTIS) U.S. Department of Commerce, Springfield, VA 22161 for $10.50 in paper and $4.00 in microfiche.)

Concepts—Sod Mover, Aug. 1978—MEDC

Aerial Burning Equipment for Plant Control, Feb. 1977—MEDC

Handbook—Equipment for Reclaiming Strip Mined Land, Feb. 1977—MEDC

Rangeland Drill Operations Handbook, BLM Tech. Note 289, Sept. 1976—SDEDC

Evaluation of the "Vari-Dozer," Feb. 1974—SDEDC

Investigation of Selected Problems in Range Habitat Improvement, Feb. 1974—SDEDC

History—Range Seeding Equipment Committee 1946-1973, Jan. 1974—MEDC

Results: 1972 Range Improvement Survey (27th annual Range Seeding Equipment Committee report), Feb. 1973—MEDC

Implement-Carrying Hitch for Forestry Use (ASAE paper), Dec. 1972—SDEDC

Efficiency and Economy of an Air Curtain Destructor Used for Slash Disposal in the Northwest (ASAE paper), Dec. 1972—SDEDC

Service & Parts Manual for the Contour Furrower Model RM 25, June 1970—SDEDC

Service & Parts Manual for the Brushland Plow, June 1968—SDEDC

Service & Parts Manual for the Rangeland Drill Models PD-10x6 and B-20x6, Aug. 1967—SDEDC

**Other Publications of Interest to VREW**

Private Water Systems Handbook, Midwest Plan Service, Iowa State University, Ames, IA 50011. $2.50

Water Systems Handbook (7th Edition), Water Systems Council, 221 North La Salle St., Chicago, IL 60601. $6

Water Well Handbook, Keith E. Anderson, Missouri Water Well and Pump Contractors Association, Inc., P.O. Box 517, Belle, MO 65013. $10

Evaluation of Pumps and Motors for Photovoltaic Water Pumping Systems, David Waddington and A. Herievich, Solar Energy Research Institute. Available from National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161. $3 microfiche; $5.25 printed copy

Rangeland Drill, reprint from "Rangelands," vol. 4, no. 3, June 1982.

Glossary of Surface Mining and Reclamation Terminology, Bituminous Coal Research, Inc., 350 Hochberg Rd., P.O. Box 278, Monroeville, PA 15146. (412) 327-1600. $2

Range Development and Improvements, 2nd edition, J.F. Vallentine. 1980, Brigham Young University Press, Provo, UT 84602. 545 pp. $18.95.

How to Build Fences with Max-ten 2—High Tensil Fence Wire, U.S. Steel Corp., P.O. Box 86 (C-1424), Pittsburgh, PA 15230. $5 plus $1.50 postage and handling

How to Design An Independent Power System, Terrance D. Paul, Best Energy Systems for Tomorrow, Inc., P.O. Box 280, Necedah, WI 54646, (608) 565-7200. $4.95

From American Association for Vocational Instructional Materials (AAVIM) Engineering Center, Athens, GA 30602:

Planning for an Individual Water System, No. 600, $6.95

Planning Fences, No. 404, $4.25

Building Fences, No. 405, $4.25

(For orders less than $10 add $1 for postage and handling; for orders over $10 add 8 percent for postage and handling.)

Range and Pasture Seeding in the Southern Great Plains, Proceedings of a symposium on the newest grasses, seeding techniques, and seed harvesting/processing equipment, Oct. 19, 1983, Vernon, TX 76384, Texas A&M Univ., Agricultural Research and Extension Center, Vernon, TX, 115 pages, $5.00. Order Seeding Proceedings Attn: Harold Wiedemann, Texas Agricultural Experiment Station, P.O. Box 1658, Vernon, TX 76384

Windmills and Pumps of the Southwest, Dick Hays and Bill Allen, Eakin Press, P.O. Box 23066, Austin, TX 78735, 110 pp. $7.95

Electric Fencing for Rangelands, Special Series 27, Colorado State Univ., Agricultural Experiment Station, Fort Collins, CO. Order from Bulletin Room, Colorado State Univ., Fort Collins, CO 80523, (303) 491-6198, $3.25 post paid

Small-Scale Solar-Powered Pumping System: The Technology, Its Economics and Advancement; main report by Sir William Halcrow and Partners in association with Intermediate Technology Power, Ltd., for the World Bank under project UNDP Project GLO/80/003, June 1983

Farm Show, published bimonthy by Farm Show Publishing, P.O. Box 704, Lakeville, MN 55044, (612) 469-5572, $9.95/year

**Drawings at SDEDC**

Pipe Harrow, RM1-01 and 02

Brushland Plow, RM2-01 to 22

Oregon Press Seeder Assembly (not complete), RM19-01 to 07

Plastic Pipe Layer Assembly, RM21-01 to 03

Reel for Laying Plastic Pipe, RM24-01

Contour Furrower, RM25-01 to 14

Rangeland Drill Deep Furrowing Arms, RM26-46 to 61

Steep-Slope Seeder, RM33-01 to 18

Demonstration Interseeder for Rocky and Brushy Areas, RM35-01 to 09

**Drawings at MEDC**

Sprig Spreader, No. 652

Sprig Harvester, No. 651

Dryland Sodder, No. 631

Tubeling Planter, No. 628

Basin Blade, No. 619

Horse Trap Trigger, No. 618

Mulch Spreader, No. 611

Tree Transport Container, No. 604

Tree Transplant Trailer, No. 602

Modified Hodder Gouger, No. 583

Dixie Sager and Modified Ely Chain, No. 568

Incendiary Grenade Dispenser, No. 522

# Attendance at Annual Meetings

| Meeting | | | Participants | | | | |
|---|---|---|---|---|---|---|---|
| *Date* | *Place* | *Presiding Chairman* | *Federal Gov't* | *State Gov't* | *Private* | *Foreign* | **Total** |
| Dec 1946 | Portland[1] | Joseph F. Pechanec | 6 | 0 | 0 | 0 | 6 |
| Dec 1947 | Ogden[1] | " " | 9 | 0 | 0 | 0 | 9 |
| Jan 1949 | Denver | " " | 15 | 0 | 0 | 0 | 15 |
| Dec 1949 | Ogden[1] | " " | 22 | 0 | 0 | 0 | 22 |
| Jan 1951 | Billings | " " | 34 | 5 | 0 | 0 | 39 |
| Jan 1952 | Boise | A. C. Hull | 45 | 9 | 0 | 0 | 54 |
| Jan 1953 | Albuquerque | " | 75 | 15 | 9 | 1 | 100 |
| Jan 1954 | Omaha | " | 63 | 8 | 3 | 5 | 79 |
| Jan 1955 | San Jose | W. W. Dresskell | 62 | 10 | 4 | 1 | 77 |
| Jan 1956 | Denver | William D. Hurst | 86 | 12 | 1 | 2 | 101 |
| Jan 1957 | Great Falls | " " | 95 | 10 | 4 | 0 | 109 |
| Jan 1958 | Phoenix | Frank C. Curtis | 87 | 9 | 3 | 0 | 99 |
| Jan 1959 | Tulsa | " " | 84 | 5 | 2 | 0 | 91 |
| Jan 1960 | Portland | " " | 98 | 10 | 3 | 3 | 114 |
| Jan 1961 | Salt Lake City | " " | 123 | 11 | 14 | 2 | 150 |
| Jan 1962 | Corpus Christi | Frank Smith | 58 | 5 | 7 | 1 | 71 |
| Jan 1963 | Rapid City | " " | 52 | 6 | 1 | 0 | 59 |
| Jan 1964 | Wichita | John Forsman | 61 | 10 | 5 | 0 | 76 |
| Jan 1965 | Las Vegas | " " | 77 | 8 | 6 | 0 | 91 |
| Feb 1966 | New Orleans | " " | 47 | 8 | 5 | 1 | 61 |
| Feb 1967 | Seattle | A. B. Evanko | 58 | 10 | 4 | 0 | 72 |
| Feb 1968 | Albuquerque | " " | 84 | 16 | 13 | 1 | 114 |
| Feb 1969 | Great Falls[1] | " " | 46 | 3 | 12 | 0 | 61 |
| Feb 1970 | Denver | " " | 81 | 8 | 11 | 0 | 100 |
| Feb 1971 | Reno | " " | 74 | 6 | 15 | 2 | 97 |
| Feb 1972 | Wash., D.C. | " " | 48 | 3 | 6 | 0 | 57 |
| Feb 1973 | Boise | " " | 60 | 7 | 7 | 4 | 78 |
| Feb 1974 | Tucson | Bill F. Currier | 61 | 12 | 10 | 14 | 97 |
| Feb 1975 | El Paso[1] | Stan Tixier | 49 | 9 | 11 | 1 | 70 |
| Feb 1976 | Omaha | " " | 50 | 17 | 12 | 0 | 79 |
| Feb 1977 | Portland | Vern L. Thompson | 63 | 26 | 31 | 10 | 130 |
| Feb 1978 | San Antonio | " " | 68 | 26 | 35 | 6 | 135 |
| Feb 1979 | Casper | Ted Russell | 74 | 35 | 72 | 12 | 193 |
| Feb 1980 | San Diego | " " | 97 | 44 | 88 | 21 | 250 |
| Feb 1981 | Tulsa | " " | 56 | 35 | 111 | 16 | 218 |
| Feb 1982 | Denver[1] | " " | 60 | 18 | 68 | 5 | 151 |
| Feb 1983 | Albuquerque | " " | 119 | 82 | 96 | 9 | 306 |
| Feb 1984 | Rapid City | Randall R. Hall | 95 | 22 | 49 | 7 | 173 |

[1] Meeting not in conjunction with Society for Range Management meeting.

# VREW Organization Membership

## Steering Committee

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Gerald E. Carlson, ARS
Beltsville, MD

Sam Miller, BIA
Washington, DC

Andy Weber, USDA-SE-EXT
Washington, DC

## Exploratory Committee

The Exploratory Committee is made up of the Steering Committee, workgroup chairmen, and appropriate Equipment Development Center personnel from Missoula and San Dimas.

# 1984 Workgroups

*Persons interested in participating in the activities of a workgroup are encouraged to write or call the workgroup chairman about their interest.*

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